December 2020

Cover Crop Performance and Potential Benefits to Wildlife in the Southern Piedmont of South Carolina

Sean Carlisle Byrd
Clemson University, scbyrd555@gmail.com

COVER CROP PERFORMANCE AND POTENTIAL BENEFITS TO WILDLIFE IN THE SOUTHERN PIEDMONT OF SOUTH CAROLINA

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Plant and Environmental Sciences

---

by
Sean Carlisle Byrd
December 2020

Accepted by:
Dara Park, Committee Chair
Joseph Lanham
Carmen Blubaugh
William Bridges

ABSTRACT

The Southern Piedmont region of South Carolina has been historically a mixture of forests, grasslands, and agroecosystems. While forests and grasslands have declined due to development, agroecosystems may be able to provide habitat for summer bird species in the region. Cover cropping is a practice in conservation agriculture that can conserve and improve soil resources, yet adoption is low in the Southeast due to long cash crop growing seasons and a lack of technical knowledge on regionally appropriate cover crops. Two field experiments were conducted in 2019 on a sandy loam in Pendleton, South Carolina to determine summer cover crop performance in the Southern Piedmont. Seven different cover crops were compared: sunflower, cowpea, sorghum, soybean, pearl millet, a multispecies blend, and a fallow treatment. Soil conditions and plant growth metrics were recorded weekly. Deer herbivory on cowpea reduced biomass in both the cowpea and mixture treatments. With exception of soybean, all treatments had similar nitrogen and phosphorus yields, with sunflower and fallow treatments having the greatest potassium yields. Cowpea had the lowest C:N ratio, while sunflower and pearl millet had C:N ratios optimal for microbial decomposition of residue. Sunflower appeared to be the healthiest and reached 100% cover and 80% flowering quickest. Sunflower is a good cover crop for nutrient cycling, confers protection from raindrop erosion, well-adapted to dry conditions, and its short life cycle permits an early or late summer cash crop planting. Summer bird diversity and equitability was studied in a Piedmont agroecosystem by conducting a modified breeding bird survey consisting of 30-point counts. Analysis of factors was conducted to see the effects these factors had on diversity indices. In addition, a sweep net survey was conducted in a nearby cover crop plot. A total of 6250 individuals were detected, represented by 48 species. Indices were greatest when surveys were conducted in the second week of June, in early morning hours, and in fescue pastures with cattle present. A total of 539 arthropods were identified, with the most common taxon of arthropods being Acrididae. There is potential for cover crops to provide habitat and forage to breeding grassland and farmland birds.

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my committee for their expertise and guidance throughout this project, and to Brad Stencil and the crew at Simpson Station; this project would not have gotten off the ground nor survived the deer if not for their help. I am extremely grateful to Isabelle Hill, I probably would have to sleep in the field on more than a few days without your help. Many thanks to my family for their support and interest in my education, and to my friends for their encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

Summer Cover Crop Performance in the Southern Piedmont

Introduction

Cover crops have been historically used in United States agriculture (Groff, 2015), however their adoption by farmers has been slow due to a lack of information about the performance of specific types, the costs of implementation, and the benefits (Hamilton et al., 2017). An increase in interest has occurred in the past decade, particularly in the East Coast USA (Hamilton et al., 2017).

Although there are many reasons why cover crops are integrated into agroecological systems, they are primarily used to release or cycle nutrients into the soil for the subsequent cash crop (Rosecrance et al., 2000). Cover crops are often utilized as a sustainable alternative to synthetic fertilizers more commonly used in conventional agriculture (Fageria et al., 2005). Leguminous cover crops are used to increase the available nitrogen (N) in the soil by fixing N_2 and are usually turned into green manure before planting the cash crop (Choi and Daimon, 2008). Cover crops other than legumes can also increase plant-available N for subsequent crops. Pearl millet cover crops can result in increased nitrogen use efficiency in corn (Rosolem et al.,2004). Planting cover crops and using them as a green manure can also allow for increased phosphorus (P) uptake in the following cash crop (Cavigelli and Thien, 2003). Certain cover crop roots have the potential to transport P from fertilizers down into lower levels of the soil profile to allow more access for following cash crop roots (Franchini et al., 2004), while others acquire P by mining subsoils (Hallama et al., 2019). Cover crops (particularly grains), offer an additional carbon source when fields would otherwise be fallow (Sainju et al., 2002). Degradation of cover crops prior to planting cash crops also allows for the cycling of potassium (K) and essential micronutrients into the system such as calcium and zinc (Nascente et al., 2015; Jahanzad et al., 2017). The release of these nutrients is largely dependent on the amount of crop present, the quality of the residue, and the timing of termination (Cobo et al., 2002).

Cover crops are also used to guard against soil loss. By intercepting rainfall, cover crops prevent splash erosion, either by using the actively growing biomass to intercept precipitation (Espejo-Pérez et al., 2013), or by slowing it down with green manure residues (Baumhardt and Lascano, 1996). Ultisols under conservation tillage that had a mix of crimson clover, vetch, and rye resulted in a 62% decrease in soil loss (Langdale, 1991). Double rows of sunflower planted in late May or early June controlled wind erosion, and trapped snow that allowed for soil water to be replenished after being used by the sunflowers (Hoag and Geiszler, 1971). Using a rainfall simulator, Gilley et al. (1986) found that increased amounts of soybean and sorghum residue resulted in less runoff, soil loss, and sediment concentration, with no runoff occurring when residue was at 13.45 t ha^{-1}.

Cover crop roots and biomass can also increase soil organic matter, which results in increased soil aggregation and aggregate stability (Fageria et al., 2005). Cover crops also have the potential to protect soil against rainfall extremes (Daniel et al., 1999), attributed to organic matter from residue allowing for slower evaporation during drought

(Busscher and Bauer, 2003) and old roots creating biopores to assist with drainage from heavy rainfall events (Cresswell and Kirkegaard, 1995). Increased biopores, soil organic matter, and soybean root colonization was documented in compacted subsoil after pearl millet was planted as a cover crop (Calonego and Rosolem, 2010).

The purpose of this study is to evaluate summer cover crop performance in the Southern Piedmont region where there is minimal information on integrating summer cover crops into agroecosystems. More specifically, replicated experiments were used to identify how long it took for cover crops to attain full cover and maturity (80% flowering), their biomass and nutrient credit, and how they influence soil volumetric water content and soil temperature.

Methods

Study Site and Experimental Design

Two experiments were conducted at Clemson University's Simpson Station Research and Education Center in Pendleton, South Carolina on a Cecil sandy loam soil. Prior to planting, the sites were tilled and fertilized at 336 kg/ha with a 15-18-24 blend, and the crops were drill seeded on May 8th, 2019.

Each of the two experiments were both designed as a randomized block, consisting of four repetitions of seven different treatments of one factor (cover crop). Each plot was 6 meters by 1.5 m, with a 1.5 m buffer in between each plot. The treatments were Peredovik sunflower (*Helianthus annuus*), Iron and Clay cowpea (*Vigna unguiculata*), Wilder Game Food sorghum (*Sorghum bicolor*), Hutcheson soybean (*Glycine max*), Leafy hybrid pearl millet (*Pennisetum glaucum*), and multispecies blend

(Pennington Rackmaster Deluxe SPP/SUMM Mix) consisting of Peredovik sunflower, Iron and Clay cowpea, Hutcheson soybean, Wilder Game Food sorghum, and Mancan buckwheat (*Fagopyrum esculentum*) (MIX), and a fallow treatment.

Soil volumetric water content and temperature, and climate data

Starting May 15th, measurements were taken with a Pogo wi-fi soil sensor (Stevens Water Monitoring Systems, Inc, Portland, Oregon) to collect weekly soil volumetric water content (ϕ_v) and soil temperature. Three measurements were taken and averaged from each plot. This continued for the duration of the ten-week experimental period. Rainfall and temperature data were collected for the experimental period and a three-year period before the start of the experiment (2016-2018) from a nearby weather station.

Soil volumetric water content and temperature, and climate data

Percent cover observations were recorded weekly until 100% cover was achieved and monitored until 80% flowering was achieved. All cover within two 0.5 m^2 transects were collected from each plot and oven-dried for 72 hours at 50 ºC to obtain dry biomass weights (Muñoz et al., 2010). Samples were then sent to the Clemson Agricultural Service Laboratory to test for N,P,K, carbon (C), and micronutrients. Total N was determined by combustion on a LECO FP528 Nitrogen Combustion Analyzer, and the remaining nutrient data was obtained by using wet ashing on an inductively coupled plasma mass spectrometer. Biomass samples were converted from g m^{-2} to kg ha^{-1} for analysis. Once nutrient concentrations were received, they were converted to kg ha^{-1} by converting from mg l^{-1} into percent, and then multiplying by the biomass yield.

Statistical analyses

The following statistical model was developed for the response variables (ϕ_v, soil temperature, time to 80% flowering, time to full cover, deer activity, biomass, C:N within biomass, as well as N, P and K credit) that included fixed effect terms for experiment, treatment, and treatment by experiment interaction; and random effect terms for repetition within experiment and residual:

$$Yijk = \mu + Ei + R(E)ij + Tk + T*Eik + \varepsilon ijk$$

where Yijk is the value of the response variable in experiment i, replication j and treatment k; μ is the overall mean; Ei is the effect of experiment i; R(E)ij is the effect of replication j within experiment i; Tk is the effect of treatment k; T*Eik is the effect of the treatment k and experiment i interaction; and εijk is the residual for experiment i, replication j and treatment k.

Analysis of variance was used to test the treatment and treatment by experiment interaction model terms for statistical significance. If effects were found to be significant, the specific nature of the effects were studied using Fisher's Protected Least Significant Difference Test to compare least squares means.

The model residuals were checked to assess the normality (Levene's test) and homogeneous variance (Shapiro-Wilks test) assumptions. The residuals plots showed evidence of non-normality for ϕ_v, N concentration, and heterogeneous variance for ϕ_v, P concentration, N yield, and K yield. Thus, these response variables were exponentially transformed and a generalized linear model analysis assuming an exponential distribution was performed. Data is presented in its raw form. Apart from soil temperature, experiment as a factor was not found significant and thus the data were pooled over the two experiments and are discussed as such.

Results and Discussion

Temperature and Rainfall

The average temperature during the experimental period was 25 ºC, with a range of 21-36 ºC, whereas the average temperature from the same time period from 2016-2018 was 25 ºC and ranged from 7-37 ºC (Figure 1.1). The experimental mean daily high temperature was higher than the historical for Weeks 0, 2-4, and 10, and lower for Weeks 2, 5 and 7 (Figure 1.1).

Total rainfall during the experimental period was 241 mm, which was almost half of the 2016-2018 mean (470 mm). Ten events with a mean volume of 24 mm per event occurred over the experimental period, with no rainfall occurring during weeks 2-4, and 6. Although 21 mm of rain occurred three days before the experiment was initiated, there was no other rainfall for 2 weeks prior. Overall, these trends portray a very dry period in comparison to the 2016-2018 historical data for the same time period. Historical mean of weekly rainfall totals ranged from 0-52 mm (Figure 1.2). Rainfall during weeks 2-4, 6, 9 and 10 were all below the corresponding weeks in the historical period (Figure 1.2)

Deer herbivory

On May 31st, deer herbivory occurred in the cowpea treatments, and on June 5th in the mixed plots, with the cowpea in that treatment being targeted. This is important to note since deer populations in the Southern Piedmont are high (40,852 between Anderson, Pickens, and Greenville counties) (Ruth, 2018) and could potentially be a significant source of damage to cover (and cash) crops (Conover et al., 2018). Herbivory continued in these plots until deer fencing was constructed around the experiments on June 28th.

Soil volumetric water content and temperature

The lack of rainfall resulted in very low ϕ_v measurements on numerous events. More than 90% of all measurements were below the instrument's accuracy (0.03 cm^3 cm^{-3}) for weeks 2, 3, and 5 - 9. Thus, data was only analyzed for Weeks 0, 1, and 4 (Table 1.1).

For weeks in which statistical analysis could be reliably performed (weeks 0,1 and 4), cover crop treatments resulted in similar ϕ_v (Table 1.1). Sandy loam soils have a field capacity of 0.12 cm^3 cm^{-3}, with a permanent wilting point of 0.04 cm^3 cm^{-3} (Weil and Brady 2016). Throughout the experimental period, measured values ranged from 0.00 – 0.20 cm^3 cm^{-3}. Only ϕ_v on week 4 was at or above field capacity, and weeks 0-3 and 5-9 were at or below permanent wilting point (Table 1.1). This was most likely due to the very dry conditions experienced during the experimental period. Perhaps there would have been more cover crop effects on ϕ_v if rainfall had not been limiting or if the experiments were irrigated. Wells et al. (2014) documented that soil under rye residue had greater ϕ_v in comparison to soil with no rye residue ($P<0.01$) in a loamy sand that received adequate rainfall in the Piedmont and coastal regions of North Carolina. Camacho et al. (2017) determined soils in North Carolina, Georgia, and Maryland that had cover crops increased ϕ_v compared to bare ground, especially in the first 30 cm of soil after a heavy rain. Similar ϕ_v from contrasting single species and multispecies cover crops was documented in silt loam in both Colorado and Nebraska (Nielsen et al., 2015), and in silty clay loam and silt loam in Kansas (Kuykendall, 2015). However, a study done in a silt loam in Milan, Tennessee found that double and multispecies cover crop treatments had higher ϕ_v than treatments with only one cover crop or no cover crops (Chu et al., 2017). Regardless, data from the present experiments should be interpreted cautiously due to many measurements being below the instrument's accuracy.

Experiment was a significant factor of soil temperatures for weeks 0, 1, 3, 5-9 of the experimental period ($p \leq 0.03$ for all weeks respectively). Perhaps due to its more west facing 0.6% slope allowing for more sun exposure (Smith, 1977), experiment 2 had a 1-4 ºC higher soil temperatures than experiment 1 (for all weeks except week 4, 6, and 9). Soil temperatures were similar regardless of cover crop treatment (Table 1.2).

Cover crop growth

Cover crops reached 50% cover at similar DAP but differed when they reached 100% cover (Table 1.3). Sunflower reached both 50% and 100% cover in the least amount of time after planting with soybean taking the longest to obtain 100% cover

(Table 1.3). It is important to determine time to cover because once a cover crop reaches this stage, it can better protect soil from splash erosion by intercepting rainfall and reduce soil evaporative losses (Busscher and Bauer, 2003; Espejo-Pérez et al., 2013). A shorter time to full cover also means that biomass will be more quickly available for nutrient cycling and minimizing the risk of inhibiting the subsequent cash crop if a cover crop is allelopathic (Balkcom et al., 2015).

Sunflower and fallow plots had 80% flowering in the least amount of time after planting, with soybean taking the longest to achieve 80% flowering (Table 1.3). Apart from cowpea and soybean, all cover other crop treatments reached 80% flowering within ranges given in literature (Casteel, 2010; GRDC, 2017; Newburn, 2014; Sheahan, 2012; University of Georgia, 2017). Cowpea's slower development was most likely due to having to recover from deer herbivory early in the experimental period. Knowing flowering time is crucial for determining termination timing, as once the crop enters the flowering state, energy is diverted from biomass growth to seed development, which is undesirable due to that regeneration of the cover crop could potentially compete for resources with the subsequent cash crop (Wayman et al., 2015). Leguminous cover crops also fix most of their nitrogen at this stage, meaning that termination at this stage is critical for ensuring maximum N cycling for subsequent cash crops (Hirpa et al., 2009). If a mixture is desired, all the cover crops utilized must have similar bloom times to ensure proper termination (Wayman et al., 2015).

Sorghum produced the highest biomass which was significantly greater than pearl millet, MIX, sunflower and the fallow plots, which were all statistically similar (Table 1.3). Fallow plots consisted primarily of Palmer amaranth (*Amaranthus palmeri*) which are adapted to drought conditions (Chahal et al., 2018; Ward et al., 2013). Multispecies cover crop mixtures have been documented to have higher biomass than single cover crop (Finney et al., 2016; Smith et al., 2014; Vasilikiotis, 2018). In the present study, biomass from the MIX was only greater than cowpea and soybean (Table 1.3). This may be due to deer herbivory on the cowpea within the MIX, and to buckwheat's poor performance in drought like conditions (Germ and Gaberšick, 2016). The lower biomass documented from the cowpea is most likely due to the deer herbivory. Soybeans produced the least amount of biomass out of all the cover crop treatments.

Nutrient biomass concentrations and yield patterns

Cover crops had different N, P, K, and C concentrations within their biomass (Table 1.4). The highest N, P, and K concentrations were documented from cowpea, with sunflower having the second highest concentrations for all three nutrients, although only statistically similar to cowpea for K concentrations (Table 1.4). Nitrogen in cowpea biomass was almost one third greater than the next highest N concentration (Table 1.4). Cowpea and soybean provide N to the soil through their association with N fixing microbes (Hirpa et al., 2009).

When accounting for biomass, a different trend became apparent with pearl millet having the highest N and P yields, being similar to all other treatments except for soybean

(Table 1.4). Soybean also had the lowest K yields (Table 1.4). Sunflower's consistently high biomass yields and having higher nutrient concentrations makes it a great option for it to fulfill multiple cover crop niches such as protecting soil from erosion, nutrient cycling, and for drought tolerance (Hoag and Geiszler, 1971; Jones and Gillett, 2005; Leather, 1983; Rodríguez-Lizana et al., 2010; Saeed, 2008).

Many of the cover crop treatments resulted in similar C:N ratios within the low to mid 30s, with cowpea having the lowest C:N ratio (16) and sunflower and pearl millet having C:N ratios closest to what is most desirable for decomposition (C:N =25 and 23 respectively), (Parnas, 1975) (Table 1.4).

Conclusion

Integrating cover crops into cropping rotations are a growing management tool in the Southern Piedmont due to documented benefits found elsewhere, such as live covers and residues protecting the soil from erosion (Espejo-Pérez et al., 2013, Langdale et al., 1991), and minimizing evaporative loss of soil water (Busscher and Bauer, 2003), increasing soil aggregation and aggregate stability (Fageria et al., 2005), a source of nutrients and water for subsequent cash crops (Rosecrance et al., 2000; Unger and Vigil, 1998), breaking up hardpans (Marshall et al., 2016), and mining nutrients deeper in subsoils (Hallama et al., 2019). Minimal information is known how commonly used summer cover crops perform in the Southern Piedmont. In the present study, drought like conditions resulted in ϕ_v measurements lower than the instrument's accuracy range and thus we were unable to determine how the cover crops influence soil water dynamics over the experimental season and for the subsequent cash crop. Sunflower reached full cover earliest, meaning it would be able to protect more of the soil from erosion and evaporative soil water loss earlier than other treatments. Sunflower produced greater quantities of biomass, and had high concentrations of N, P and K, and as a result had more nutrients to cycle back into the soil. Sunflower's C:N ratio of 25:1 would promote microbial decomposition of the cover. Sunflower reached a termination date at an earlier time than the other cover crop treatments, offering a farmer flexibility. For example, sunflowers could be planted later in summer after an early summer cash crop and be ready to terminate before planting a cool-season crop. Sunflower could also be planted earlier to accommodate a summer cash crop. Sunflower also appeared to be the healthiest treatment during the experiment, even with the apparent low ϕ_v.

A concern during the experiment was white-tailed deer predation on cowpea which was found in MIX and cowpea plots, which limited biomass and delaying full cover and 80% flowering times. Despite these issues, cowpea had the highest nutrient concentrations in tissue, so if cowpea is the cover crop desired for nutrient cycling, further research is needed to find either a more palatable crop to discourage deer feeding on cowpea, or other ways to prevent deer grazing on cowpea. The authors have spoken with farmers within the region (as well as throughout South Carolina) who have also voiced heavy deer herbivory on cowpea. Instead of using cowpea with the intent for nutrient cycling, perhaps it should be incorporated into a multispecies cover crop mix at a low rate (approximately 5.6 kg ha-1) as a bait crop, meaning to encourage deer to feed on cowpea instead of the desired cover crop.

Figures and Tables

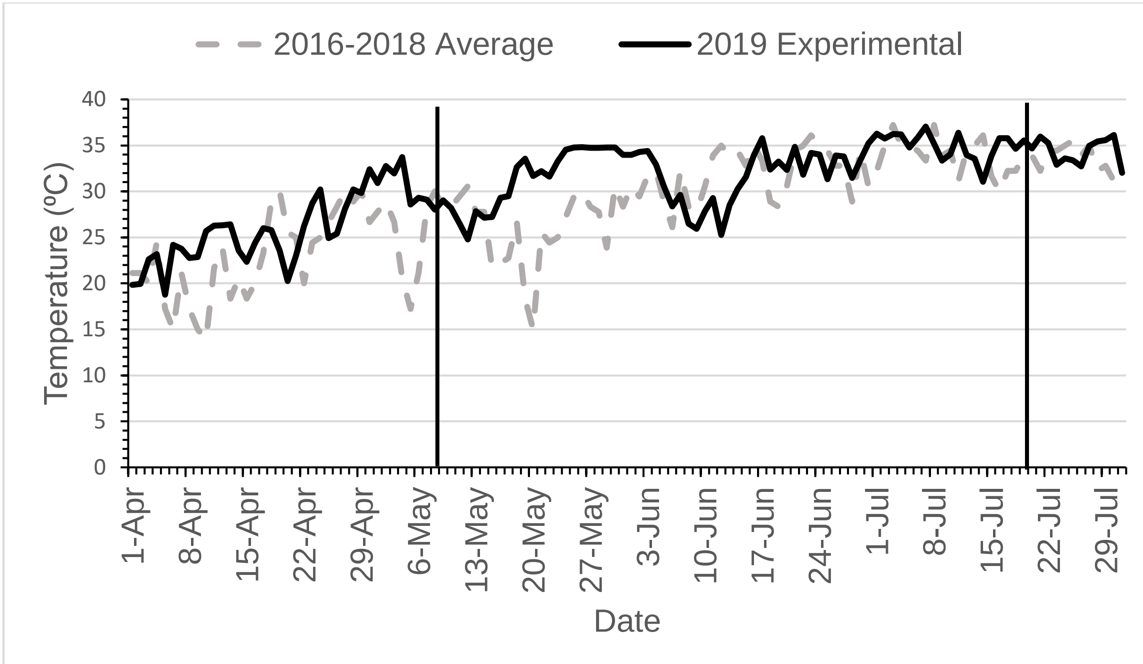

Figure 1.1: Daily high temperatures during the 2019 experimental period and the 2016-2018 historical mean at Clemson University's Simpson Experiment Station in Pendleton, South Carolina. Lines indicate the days in which the experiments began and ended during 2019.

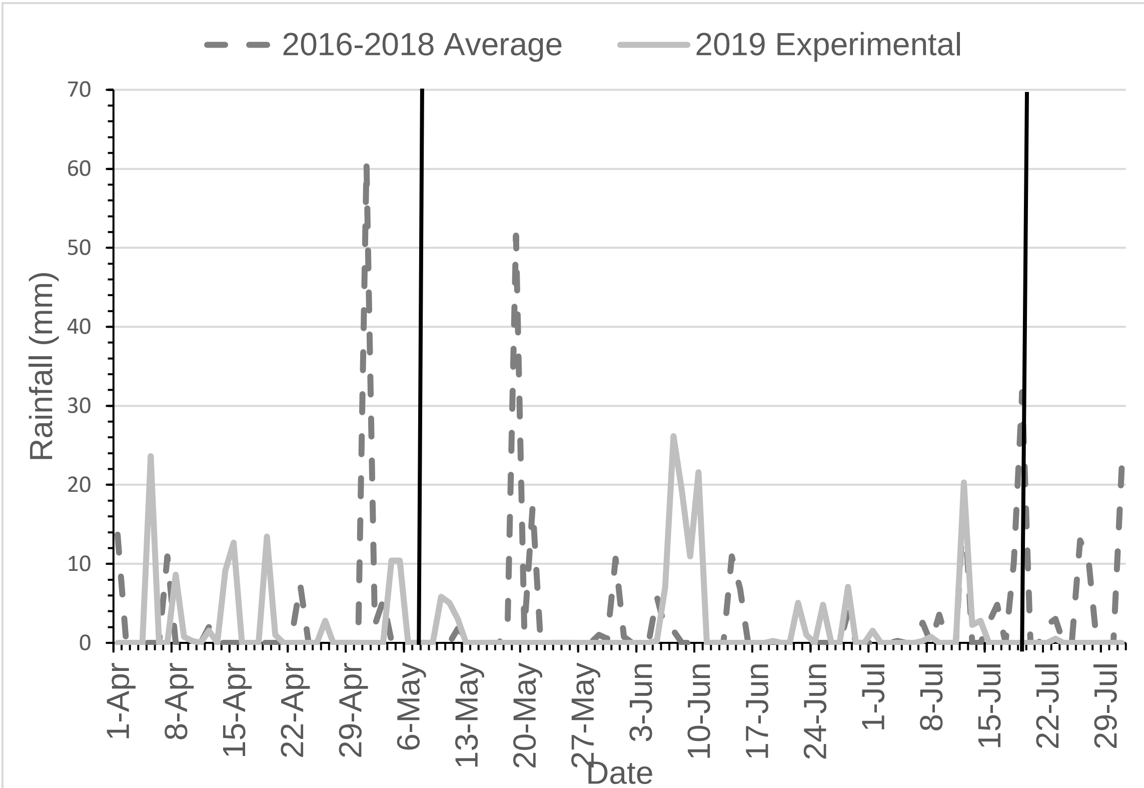

Figure 1.2: Daily rainfall during the 2019 experimental period and the 2016-2018 historical mean at Clemson University's Simpson Experiment Station in Pendleton, South Carolina. Lines indicate the days in which the experiments began and ended during 2019.

Table 1.1. LS means ϕ_v (cm^3 cm^{-3}) in the upper 6 cm of soil under cover crop treatments over the 2019 experimental period. Values are pooled from the two experiments. Due to measured values lower than the instruments accuracy, statistical analysis was only conducted on data from weeks 0,1 and 4.

Trt	Wk 0	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9
Sunflower	0.06	0.06	0.03	0.02	0.12	0.01	0.00	0.00	0.00	0.02
Cowpea	0.06	0.06	0.03	0.02	0.12	0.01	0.00	0.00	0.00	0.01
Sorghum	0.07	0.07	0.04	0.03	0.12	0.01	0.00	0.00	0.00	0.02
Soybean	0.06	0.06	0.03	0.02	0.12	0.01	0.01	0.00	0.01	0.02
P. Millet	0.06	0.06	0.03	0.02	0.13	0.01	0.00	0.00	0.01	0.02
Mix	0.06	0.06	0.03	0.02	0.11	0.01	0.00	0.00	0.01	0.02
Fallow	0.06	0.06	0.05	0.03	0.12	0.00	0.00	0.00	0.01	0.02
P value	0.3869	0.5451	n/a	n/a	0.0872	n/a	n/a	n/a	n/a	n/a
Std Error	0.011	0.002	0.00	0.00	0.005	0.00	0.00	0.00	0.00	0.00

α LS means followed by the same letter within a column are statistically similar when compared using a Student's T test at a significance level 0.05.

Table 1.2. Weekly least square means for temperature (ºC) in the upper 6 cm of soil under cover crop treatments over the 2019 experimental period. Values are pooled over the two experiments.

Trt	Wk 0	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9
Sunflower	29.2	36.5	37.9	32.9	37.9	34.5	24.2	27.3	32.3	30.4
Cowpea	25.8	36.6	37.7	33.6	38.3	34.2	24.4	27.5	32.0	30.4
Sorghum	29.6	36.4	37.9	33.0	37.9	33.8	24.1	27.2	32.1	30.4
Soybean	29.4	36.4	37.8	33.7	38.5	32.3	24.2	27.0	31.8	30.2
P. Millet	29.1	36.3	39.7	33.5	38.1	32.6	23.8	29.2	31.9	30.4
Mix	26.5	36.4	38.0	33.7	38.5	32.4	24.1	28.4	31.7	30.3
Fallow	29.6	36.7	38.6	33.5	38.4	33.4	23.9	30.0	31.7	30.2
P value	0.5470	0.9733	0.3375	0.1796	0.3760	0.3092	0.9870	0.3050	0.3413	0.4499
Std Error	1.7	0.3	1.4	0.7	0.5	1.2	0.5	1.1	0.7	0.3

α LS means followed by the same letter within a column are statistically similar when compared using a Student's T test at a significance level 0.05.

Table 1.3: Least square means for 50% and 100% cover (days after planting, DAP), 80% flowering, and biomass at 80% flowering (kg ha^{-1}) of summer cover crops planted in the Southern Piedmont.

	50% Cover (DAP)	100% Cover (DAP)	80% Flowering (DAP)	Biomass (kg ha^{-1})
Sunflower	35	64 d$^{\alpha}$	60 c	2065 b
Cowpea	38	84 b	72 b	1316 c
Sorghum	41	72 c	72 c	2911 a
Soybean	39	148 a	132 a	787 d
P. Millet	35	72 c	70 bc	2396 b
Mix	39	71 c	69 bc	2032 b
Fallow	39	64 d	63 bc	2372 b
P Value	0.2	<0.0001	<0.0001	<0.0001
Std Error	2.45	0.2273	3.6	186

α LS means followed by the same letter within a column are statistically similar when compared using a Student's T test at a significance level 0.05.

Table 1.4. Least square means for cover crop nitrogen (N), phosphorus (P), potassium (K), and carbon (C) concentrations (mg g^{-1}), yields (kg ha^{-1}), and C:N ratio at time of termination (80% bloom).

	N	P	K	C	N yield	P yield	K yield	C yield	C:N
	-------------------mg g^{-1}------------------------				-------------------kg ha^{-1}--------------------				
Sunflower	1.85 b$^{\alpha}$	0.18 b	2.84 a	44.08 ab	39 a	4 a	59 a	907 b	25 b
Cowpea	2.72 a	0.24 a	2.96 a	42.25 bc	36 a	3 a	39 b	553 c	16 c
Sorghum	1.32 c	0.12 b	1.63 c	45.05 a	38 a	3 a	49 ab	1300 a	36 a
Soybean	1.64 bc	0.16 b	1.53 c	44.84 a	13 b	1 b	12 c	351 c	32 ab
P. Millet	1.64 bc	0.15 b	2.21 b	43.38 ab	41 a	4 a	55 ab	1032 b	23 b
Mix	1.62 bc	0.16 b	2.20 b	43.18 abc	32 a	3 a	44 ab	871 b	31 ab
Fallow	1.62 bc	0.17 b	2.54 ab	41.45 c	32 a	4 a	61 a	978 b	33 ab
P Value	<0.0001	0.0137	<0.0001	0.0078	0.0100	0.0119	0.0005	<0.0001	0.0014
Std Error	0.1422	0.02	0.1692	1.0843	4.67	0.5584	6.8937	0.0014	3

α LS means followed by the same letter within a column are statistically similar when compared using a Student's T test at a significance level 0.05.

Works Cited

Balkcom, K.S., Duzy, L.M., Kornecki, T.S., Price, A.J., 2015. Timing of Cover Crop Termination: Management Considerations for the Southeast. Crop. Forage Turfgrass Manag. 1, cftm2015.0161. https://doi.org/10.2134/cftm2015.0161

Baumhardt, R.L., Lascano, R.J., 1996. Rain Infiltration as Affected by Wheat Residue Amount and Distribution in Ridged Tillage. Soil Sci. Soc. Am. J. 60, 1908–1913. https://doi.org/10.2136/sssaj1996.03615995006000060041x

Busscher, W.J., Bauer, P.J., 2003. Soil strength, cotton root growth and lint yield in a southeastern USA coastal loamy sand. Soil Tillage Res. 74, 151–159. https://doi.org/10.1016/j.still.2003.06.002

Calonego, J.C., Rosolem, C.A., 2010. Soybean root growth and yield in rotation with cover crops under chiseling and no-till. Eur. J. Agron. 33, 242–249. https://doi.org/10.1016/j.eja.2010.06.002

Casteel, S., 2010. Soybean Station Delivering First Class Information Soybean Physiology: How Well Do You Know Soybeans?

Cavigelli, M.A., Thien, S.J., 2003. Phosphorus Bioavailability following Incorporation of Green Manure Crops. Soil Sci. Soc. Am. J. 67, 1186–1194. https://doi.org/10.2136/sssaj2003.1186

Chahal, P.S., Irmak, S., Jugulam, M., Jhala, A.J., 2018. Evaluating Effect of Degree of

Water Stress on Growth and Fecundity of Palmer amaranth (Amaranthus palmeri) Using Soil Moisture Sensors. Weed Sci. 66, 738–745. https://doi.org/10.1017/wsc.2018.47

Choi, B., Daimon, H., 2008. Effect of hairy vetch incorporated as green manure on growth and N uptake of sorghum crop. Plant Prod. Sci. 11, 211–216. https://doi.org/10.1626/pps.11.211

Chu, M., Jagadamma, S., Walker, F.R., Eash, N.S., Buschermohle, M.J., Duncan, L.A., 2017. Effect of Multispecies Cover Crop Mixture on Soil Properties and Crop Yield. Agric. Environ. Lett. 2, 170030. https://doi.org/10.2134/ael2017.09.0030

Cobo, J.G., Barrios, E., Kass, D.C.L., Thomas, R.J., 2002. Decomposition and nutrient release by green manures in a tropical hillside agroecosystem. Plant Soil 240, 331–342. https://doi.org/10.1023/A:1015720324392

Conover, M.R., Butikofer, E., Decker, D.J., 2018. Wildlife damage to crops: Perceptions of agricultural and wildlife leaders in 1957, 1987, and 2017. Wildl. Soc. Bull. 42, 551–558. https://doi.org/10.1002/wsb.930

Cresswell, H.P., Kirkegaard, J.A., 1995. Subsoil amelioration by plant roots—the process and the evidence. Aust. J. Soil Res. 33, 221–239. https://doi.org/10.1071/SR9950221

Daniel, J.B., Abaye, A.O., Alley, M.M., Adcock, C.W., Maitland, J.C., Wilkinson, W., 1999. Winter annual cover crops in a no-till cotton production system in Virginia, in: Acta Horticulturae. pp. 99–105. https://doi.org/10.17660/actahortic.1999.504.10

Espejo-Pérez, A.J., Rodríguez-Lizana, A., Ordóñez, R., Giráldez, J. V., 2013. Soil Loss and Runoff Reduction in Olive-Tree Dry-Farming with Cover Crops. Soil Sci. Soc. Am. J. 77, 2140–2148. https://doi.org/10.2136/sssaj2013.06.0250

Fageria, N.K., Baligar, V.C., Bailey, B.A., 2005. Role of cover crops in improving soil and row crop productivity. Commun. Soil Sci. Plant Anal. https://doi.org/10.1080/00103620500303939

Finney, D.M., White, C.M., Kaye, J.P., 2016. Biomass production and carbon/nitrogen ratio influence ecosystem services from cover crop mixtures. Agron. J. 108, 39–52. https://doi.org/10.2134/agronj15.0182

Franchini, J.C., Pavan, M.A., Miyazawa, M., 2004. BRAZILIAN ARCHIVES OF BIOLOGY AND TECHNOLOGY Redistribution of Phosphorus in Soil Through Cover Crop Roots. Brazilian Arch. Biol. Technol. 47, 381–386.

Germ, M., Gaberšick, A., 2016. The Effect of Environmental Factors on Buckwheat, in: Molecular Breeding and Nutritional Aspects of Buckwheat. Elsevier Inc., pp. 273–278. https://doi.org/10.1016/B978-0-12-803692-1.00021-3

Gilley, J.E., Finker, S.C., Vervel, G.E., 1986. Runoff and Erosion as Affected by Sorghum and Soybean Residue. Trans. ASCE 29, 1605–1610.

GRDC, 2017. Sorghum - PLANT GROWTH AND PHYSIOLOGY.

Groff, S., 2015. The past, present, and future of the cover crop industry. J. Soil Water

Conserv. 70, 130A-133A. https://doi.org/10.2489/jswc.70.6.130A

Hallama, M., Pekrun, C., Lambers, H., Kandeler, E., 2019. Hidden miners – the roles of cover crops and soil microorganisms in phosphorus cycling through agroecosystems. Plant Soil. https://doi.org/10.1007/s11104-018-3810-7

Hamilton, A. V, Mortensen, D.A., Allen, M.K., 2017. The state of the cover crop nation and how to set realistic future goals for the popular conservation practice. J. Soil Water Conserv. https://doi.org/10.2489/jswc.72.5.111A

Hirpa, T., Gebrekidan, H., Tesfaye, K., Hailemariam, A., 2009. Biomass and Nutrient Accumulation of Green Manuring Legumes Terminated at Different Growth Stages. East African J. Sci. 3. https://doi.org/10.4314/eajsci.v3i1.42782

Hoag, B.K., Geiszler, G.N., 1971. Sunflower Rows To Protect Fallow From Wind Erosion. Farm Res. 7–12.

Jahanzad, E., Barker, A. V, Hashemi, M., Sadeghpour, A., Eaton, T., Park, Y., 2017. Improving yield and mineral nutrient concentration of potato tubers through cover cropping. F. Crop. Res. 212, 45–51. https://doi.org/10.1016/j.fcr.2017.06.023

Kuykendall, M.B., 2015. Biomass production and changes in soil water with cover crop species and mixtures following no-till winter wheat.

Langdale, G.W., 1991. Cover crop effects on soil erosion by wind and water. Cover Crop. clean water. Proc. Conf. Jackson, 1991 15–22.

Marshall, M.W., Williams, P., Nafchi, A.M., Maja, J.M., Payero, J., Mueller, J., Khalilian, A., 2016. Influence of Tillage and Deep Rooted Cool Season Cover Crops on Soil Properties, Pests, and Yield Responses in Cotton. Open J. Soil Sci. 06, 149–158. https://doi.org/10.4236/ojss.2016.610015

Muñoz, J.D., Finley, A.O., Gehl, R., Kravchenko Sasha, S., 2010. Nonlinear hierarchical models for predicting cover crop biomass using Normalized Difference Vegetation Index. Remote Sens. Environ. 114, 2833–2840. https://doi.org/10.1016/j.rse.2010.06.011

Nascente, A.S., Stone, L.F., Crusciol, C.A.C., 2015. Soil chemical properties affected by cover crops under no-tillage system. Rev. Ceres 62, 401–409. https://doi.org/10.1590/0034-737X201562040010

Newburn, J., 2014. Plant of the Month for September: Sunflower [WWW Document]. URL https://extension.tennessee.edu/news/Pages/POM-2014-09.aspx#.Xnkx1ohKiUm (accessed 3.23.20).

Nielsen, D.C., Lyon, D.J., Hergert, G.W., Higgins, R.K., Calderón, F.J., Vigil, M., 2015. Cover crop mixtures do not use water differently than single-species plantings. Agron. J. 107, 1025–1038. https://doi.org/10.2134/agronj14.0504

Parnas, H., 1975. Model for decomposition of organic material by microorganisms. Soil Biol. Biochem. 7, 161–169. https://doi.org/10.1016/0038-0717(75)90014-0

Roberts, P.A., Matthews, W.C., Ehlers, J.D., 2005. Root-knot nematode resistant cowpea cover drops in tomato production systems. Agron. J. 97, 1626–1635.

https://doi.org/10.2134/agronj2004.0290

Rodríguez-Lizana, A., Carbonell, R., González, P., Ordóñez, R., 2010. N, P and K released by the field decomposition of residues of a pea-wheat-sunflower rotation. Nutr. Cycl. Agroecosystems 87, 199–208. https://doi.org/10.1007/s10705-009-9328-x

Rosecrance, R.C., Mccarty, G.W., Shelton, D.R., Teasdale, J.R., 2000. Denitrification and N mineralization from hairy vetch (Vicia villosa Roth) and rye (Secale cereale L.) cover crop monocultures and bicultures. Plant Soil 227, 283–290. https://doi.org/10.1023/A:1026582012290

Rosolem, C.A., Pace, L., Crusciol, C.A.C., 2004. Nitrogen management in maize cover crop rotations, Plant and Soil.

Saeed, R., 2008. Breeding sunflower (Helianthus annuus L .) for drought tolerance. Commun. Biometry Crop Sci. 3, 29–44.

Sainju, U.M., Singh, B.P., Whitehead, W.F., 2002. Long-term effects of tillage, cover crops, and nitrogen fertilization on organic carbon and nitrogen concentrations in sandy loam soils in Georgia, USA. Soil Tillage Res. 63, 167–179. https://doi.org/10.1016/S0167-1987(01)00244-6

Sheahan, C., 2012. Plant Guide COWPEA Vigna unguiculata (L.) Walp.

Smith, J.M.B., 1977. Vegetation and Microclimate of East- and West-Facing Slopes in the Grasslands of MT Wilhelm, Papua New Guinea. J. Ecol. 65, 39.

https://doi.org/10.2307/2259061

Smith, R.G., Atwood, L.W., Warren, N.D., 2014. Increased productivity of a cover crop mixture is not associated with enhanced agroecosystem services. PLoS One 9. https://doi.org/10.1371/journal.pone.0097351

Unger, P.W., Vigil, M.F., 1998. Cover crop effects on soil water relationships. J. Soil Water Conserv. 53, 200–207.

University of Georgia, E., 2017. Pearl Millet for Grain | UGA Cooperative Extension [WWW Document]. Bull. 1216. URL https://extension.uga.edu/publications/detail.html?number=B1216&title=Pearl Millet for Grain (accessed 3.23.20).

USDA, 2019. USDA/NASS 2018 State Agriculture Overview for Wyoming [WWW Document]. USDA/NASS. URL https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=SOUTH CAROLINA (accessed 5.6.20).

Vasilikiotis, C., 2018. Evaluation of cover crop mixtures for weed management and soil Evaluation of cover crop mixtures for weed management and soil fertility improvement in organic agriculture fertility improvement in organic agriculture.

Ward, S.M., Webster, T.M., Steckel, L.E., 2013. Palmer Amaranth (Amaranthus palmeri): A Review. Weed Technol. 27, 12–27. https://doi.org/10.1614/wt-d-12-00113.1

Wayman, S., Cogger, C., Benedict, C., Burke, I., Collins, D., Bary, A., 2015. The influence of cover crop variety, termination timing and termination method on mulch, weed cover and soil nitrate in reduced-tillage organic systems. Renew. Agric. Food Syst. 30, 450–460. https://doi.org/10.1017/S1742170514000246

Wells, M.S., Reberg-Horton, S.C., Mirsky, S.B., 2014. Cultural Strategies for Managing Weeds and Soil Moisture in Cover Crop Based No-Till Soybean Production. Weed Sci. 62, 501–511. https://doi.org/10.1614/ws-d-13-00142.1

CHAPTER TWO

The Role of Agroecosystems to Support Southern Piedmont Summer Avian Communities: Avian Diversity and Equitability Indices and the Potential for Cover Crops as Avian Arthropod Forage Resources

Introduction

Approximately a third of South Carolina is within the Southern Piedmont region of the USA (Edgar 1998) which historically harbored both grasslands and forested lands and is home to a wide array of bird species (Johnston and Odum 1956a; Edwards, Nicole T., Otis 1999; Davis et al. 2002). Piedmont prairies are a type of grassland found in this region, and are often characterized by shallow low fertility soils with high shrink/swell capacities and wide variations in soil available water (Tompkins et al. 2010).The Piedmont prairies of the past are mostly gone due to agricultural intensification (Wood et al. 2000) and are now primarily found along roadsides and right of ways (Edgar 1998, Benson 2011; Tompkins and Bridges 2013). The state's forests are home to many birds, some of which also inhabit grasslands (Kilgo et al. 1973, 2002; Bollinger 2001). The Clemson Experimental Forest surrounding the Clemson University's main campus is located within the Southern Piedmont and is a result of conservation efforts to restore the impoverished landscape that developed from previous poor farming practices (Sorrells 1984).

Grasslands and forests comprise 11 and 83 % of the world's endemic bird areas respectively (White et al. 2000; Matthews et al. 2001). Regionally, grassland birds were common on the East Coast during the time of European settlement, and decline began between the nineteenth and mid-twentieth century (Askins 1999; Ceballos et al. 2010). At this time, grassland and forest loss occurred due to the intensification of agriculture, leading to a loss of bird diversity from the change in ecosystem composition and structure and the effects of farming inputs and management practices (Wood et al. 2000). While forests in some areas have regrown, biodiversity is vastly reduced due to timber production (Matthews et al. 2001). These changes lead to fragmentation resulting in the loss of species richness across a landscape (Robinson et al. 1999; Lindborg et al. 2014). For example, North America has 20% of its central grasslands intact, however, most are utilized for grazing, which alters the structure and diversity of the ecosystem (Bardgett and Cook 1998; Ceballos et al. 2010).

Grasslands provide food and habitat for a diversity of flora and fauna, as well as productive land for agricultural systems including many major grain crops, and forage for livestock (White et al. 2000). Forests are also diverse areas that provide food, as well as timber and other commodities, and can be used for livestock production through silvopasture (Matthews et al. 2001). Some bird grassland species are able to use farmland, especially field borders and farms with low-intensity land use (Wretenberg et al. 2010). Farmland that has been converted to perennial habitat under the Natural Resource Conservation Service's Conservation Reserve Program, provide valuable habitat for arthropod prey, which is crucial for many bird species, especially in the nesting and breeding season (McIntyre and Thompson 2003; Robertson et al. 2011). Cash crop systems are typically monocultures, which vastly reduce biodiversity, while polycultures better preserve diversity (Ghazali et al. 2016). Integrating cover crops into a crop rotation can also support breeding and migrating bird species (Wilcoxen et al.

2018a). Adding trees to arable fields as short rotation coppices also can increase bird abundance and diversity due to increased structural diversity (Berg 2002). Light to moderate grazing can be beneficial, with heavy grazing reducing plant diversity (Risser and Wilson 1988), and subsequently bird diversity.

Despite the use of farmland by some grassland birds, many populations are in steep decline due to lack of suitable habitat (McCracken 2005; Hill et al. 2014), including species of sparrow, dickcissel, bobolink, and several raptors and upland game birds (McCracken 2005). Degradation of remaining habitats and a lack of habitat connectivity may be too much to reverse declines (or even slow down) of certain bird populations (With et al. 2008). Bird community characteristics within traditional agroecosystems are unknown in the Southern Piedmont. The influence on bird populations by including non-traditional agroecosystems such as cover crops is also unknown. In multispecies plots with a high diversity of crops, overall diversity usually is greater than single-species plots due to diversity begetting diversity (Mayer and Pimm 1997). Cover crops can alter C:N ratio in the soil, influencing the community of soil microbes present (Reddy et al. 2003). In addition to the type of cover crop influencing the soil microbial community, nematodes can react to the increased presence of microbes to feed on (Leslie et al. 2017). Increased diversity can further help with arthropod insect pest management in cash crops by potentially attracting a diverse suite of arthropod predators to feed on any pest present (Leslie et al. 2017). For example, when sunflowers reach 15 cm in height, they attract arthropod predators, with parasitoids attracted upon reaching the flowering stage (Jones and Gillett, 2005). Cover crops have the potential to provide imperiled avian grassland specialists with habitat and arthropod food, especially in the breeding season when protein makes up most of their diet during this time (McIntyre and Thompson 2003; Robertson et al 2011) Greater vegetative structure in cropping systems integrating cover crops leads to higher nesting success in grassland birds (Wilcoxen et al. 2018a).

Bird community populations are commonly characterized by richness (is the number of species in an area), and evenness (*J*) (how well distributed species abundance is in a community) (Wilsey and Potvin 2000). Another diversity measure, the Shannon-Weiner index (H'), looks at diversity based on both richness and evenness (Allen et al. 2009). Biodiversity and equitability are believed to be important to ecosystem functions, and has been declining due to habitat loss (Dickson and Wilsey 2009). Measuring biodiversity is a key driver of identifying appropriate conservation decisions and measures (Mcdonald et al. 2010), as well as a tool to assess the health and stability of an ecosystem (Obasi et al. 2013). Baseline data is needed to ensure management plans are created that allow the production of resources for humanity while maintaining biodiversity (Niemelä 2000; Regan et al. 2007).

The purpose of this study was to determine summer bird community populations in a complex Southern Piedmont agroecosystem. The main objective was to simply capture summer bird diversity, richness, and evenness to use as a baseline for making and assessing impact of future land management decisions.   The second objective was because diversity begets diversity, we wanted to know how cover crops may potentially impact bird diet options. As integrating cover crops into agroecosystems gains interest by farmers in the region, they may become a significant source of shelter and food for arthropods that are a part of bird diets.

Methods

Study Site and Experimental Design

A bird survey modified from Fletcher and Koford (2002) was conducted on a 14.8 km tract of land at Clemson University's Simpson Station Research and Education Center, Pendleton, South Carolina (Figure 2.1). Thirty observation sites were spaced approximately 200 meters apart from each other. The habitats consisted of fescue pasture with and without cattle, fescue pasture with a forage radish cover crop with and without cattle, cornfields, and mixed-use (areas containing a mixture of pasture, experimental plots, corn and/or bodies of water).

Observations were made three times a week, from 22 May 2019 to 12 July 2019, for a total of 18 observation events. The first site in which observations began was randomized each day with observations beginning at 06:00. At the start of each point count, temperature, wind speed, sky code, time (Robbins 1981), cattle presence (yes/no), habitat (fescue, fescue with cover, mixed-use, and corn), and disturbances (man-made, natural, mix, none) were recorded. Habitat was determined by observing the type of landcover present, and disturbances were either loud noises that prevented the observer from hearing any birds present or could make birds leave the area during the point count. Temperatures were grouped by 2.78 ^{o}C and the time of the survey was grouped by hour (i.e. 0600-0659 was grouped as 6) (Robbins 1981). Sampling was not conducted during rainfall or high winds (>30.5 km h^{-1}) (Fletcher and Koford 2002). Upon arriving at each point, one minute was allowed to pass before sampling to minimize disturbance related to observer approach. For the following five minutes, all birds that were seen or heard were recorded (Sauer et al. 2003).

Species diversity was estimated using the Shannon-Wiener index (H'), richness, and equitability by Pielou evenness (*J*) (Wilsey and Potvin 2000; Ma 2005; Pillsbury et al. 2011; Hovick et al. 2015) via the vegan package in R (Oksanen et al. 2009).
At one of the sites within the survey area, cover crop plots were established as a randomized block design, with four replications. The experiment was repeated in two locations within the site field. The cover crops were selected based on their common use in South Carolina. The cover crop plots were Peredovik sunflower (*Helianthus annuus*), Iron and Clay cowpea (*Vigna unguiculata*), Wilder Game Food sorghum (*Sorghum bicolor*), Hutcheson soybean (*Glycine max*), Leafy hybrid pearl millet (*Pennisetum glaucum*), a fallow treatment, and a multispecies blend (Pennington Rackmaster Deluxe SPP/SUMM Mix) consisting of Peredovik sunflower, Iron and Clay cowpea, Hutcheson soybean, Wilder Game Food sorghum, and Mancan buckwheat (*Fagopyrum esculentum*) (MIX).

Once the plants reached approximately 61 cm (June 14th), they were sweep netted every two weeks for approximately a month and a half. Six passes through each plot was performed with the net, and the arthropods were placed within a 1 L zip-loc bag, and then euthanized by freezing (Buffington and Redak 1998).

After capture, arthropods were taken to the Clemson University Arthropod collection Database to be pinned and labeled according to guidelines, with arachnids and juvenile specimens being preserved in 80% ethanol and labeled (Schauff 2001). Arthropod specimens were identified up to their taxonomic families in the lab according to diet life histories of the species detected in the survey (Frederick and Siegel-Causey 2000; McIntyre and Thompson 2003) and then counted (Hooks et al. 2003).

All cover within two 0.5 m^2 transects were collected from each plot and oven-dried for 72 hours at 50 ºC to obtain dry biomass weights (Muñoz et al., 2010). Samples were then sent to the Clemson Agricultural Service Laboratory to test for total nitrogen (N) and carbon (C) was determined by combustion on a LECO FP528 Nitrogen Combustion Analyzer.

Statistical analyses

Avian Diversity, Richness and Equitability

Diversity and equitability data were analyzed based on a main effects model with habitat, wind and sky code, temperature, date, and time of day as factors with habitats visited as replications. Analysis of variance (ANOVA) was used to test the significance of the model factors. ANOVA assumptions were evaluated and found to be satisfied. Since wind code, sky code and temperature were found not significant, they were removed as variables in the subsequent fit models made for the diversity indices and species. For all three indices, habitat, time of day, and date were utilized to identify the best fit model by best subset analysis and checked with lasso and elastic net analyses. When factors were found to be significant for the models, individual species were analyzed to attempt to further understand the nature of the factor's impact on diversity. Fit models using habitat, hour, and date were also performed for the species observed that are of highest conservation concern in South Carolina: Field sparrow (*Spizella pusilla*), Eastern meadowlark (*Sturnella magna*), and Grasshopper sparrow (*Ammodramous savannarum*). While Eastern kingbird (*Tyrannus tyrannus*), Green heron (*Butorides virescens*), Wood duck (*Aix sponsa*), and Chimney swift (*Chaetura pelagica*) were species of high conservation concern as well, fit models could not be completed since their detections rates were too low. Statistics were conducted using JMP Version 15 (SAS, Cary, NC, USA) with a significance level set at 0.05.

Cover Crop Evaluation for Avian Forage Potential

Arthropod data was performed in R to compare arthropod abundance within cover crop type assuming a Poisson distribution, and then an information theoretic approach was applied to identify the strongest uncorrelated crop-based predictors of herbivore abundance using the variables biomass and percent foliar carbon and nitrogen (Blubaugh et al. 2018). Competing models were evaluated using the Mumin package and the best fit models were chosen based on the fewest variables within the Akiaike information criterion values of the minimum (Blubaugh et al. 2018).

Results

Weather

The temperature during the survey period ranged from 17 ^{o}C to 37 ^{o}C, with an average of 29 ^{o}C (Figure 2.2). There were eight rainfall events, with the highest rain event resulting in 26 mm of rain on June 7th (Figure 2.2). The wind averaged between 2 and 5 k hr^{-1}, and never exceeded 19.3 k hr^{-1}, and the sky was on average partly cloudy or variable.

Bird Community Composition

A total of 6250 birds were detected during the survey, representing 48 species, with Eastern meadowlark, Red-winged blackbird (*Agelaius phoeniceus)*, Grasshopper sparrow, American crow (*Corvus brachyrhynchos)*, Mourning dove (*Zenadia macroura*), Dickcissel (*Spiza americana*), and Eastern bluebird (*Sialia sialis)* as the most common species (Figure 2.3). Thirty-nine species were below 4% of the total species count with only one individual from Green heron and Pileated woodpecker (*Dryocopus pileatus*) (Figure 2.3).

Factor Influence on Diversity Indices

Date, time of day, and habitat influenced H' and *J*, while date, and habitat were found to be significant for species richness (Table 2.1).

The three indices appear to follow the same trend with a decline beginning approximately in the middle of the survey period (Figure 2.4a). There was less variation in *J* over the survey period in comparison to H' and species richness indices. Average daily H' measured between 0.81 and 1.6 throughout the season, with the highest daily H' being found on 17 June 2019, and the lowest on 10 July 2019. Average daily *J* measured between 0.21 and 0.32, with the highest daily *J* found on 5 June 2019, and the lowest on 10 July 2019. Daily richness was between 6 and 11 species detected, with the highest amount of species being detected on 21 June 2019, and the lowest amount of species being detected on 5 July 2019.

The surveys were conducted from 05:00 to 10:00, with 47.5 % of the survey conducted during 08:00-09:00. The H' and J indices increased in the early morning, followed by reduced index values in the later hours of the survey after a sharp decline at 08:00 (Figure 2.4b). Surveying birds at 08:00 resulted in the lowest H' and J indices (Figure 2.4b).

Except for fescue and radish without cattle, all other fescue habitats had the highest diversity and equitability indices during the survey (Table 2.2). Cornfields resulted in the lowest diversity and equitability indices among the habitat types (Table 2.2). It should be taken into consideration that the 08:00 hour and cornfields were confounding effects.

Best Fit Models

Habitat and Time of day were the greatest predictors of H' diversity and *J* (Table 2.3a and 2.3b). Habitat, Time of Day, and Date were the greatest predictors of species richness (Table 2.3c).Habitat and hour were the greatest predictors for Grasshopper sparrow presence (Table 2.4a).Habitat was the greatest predictor of Eastern meadowlark and Field sparrow presence (Tables 2.4b and 2.4c). Further analysis identified that fescue without cattle resulted in the most eastern meadowlark present, fescue with cover and no cattle resulted in the most grasshopper sparrow present, and mixed plots resulting in the most field sparrow present, with the 6 o'clock hour resulting in the most grasshopper sparrows present.

Arthropods for Avian Forage Potential

Eight arthropod families were identified with the most common families being Acrididae, followed by Scarabeidae (Figure 2.5). The number of taxon identified were less than documented in other systems (Rudd and Jensen 1977; Siemann et al. 1999; Mosquera-Losada et al. 2005; Doxon et al. 2011) which is likely due to the focus on arthropod taxa of dietary importance to grassland birds (McIntyre and Thompson 2003) and of only > 5mm in size. Pearl millet and soybean had the highest number of arthropods per sampling event, which was with sunflower and cowpea having the lowest (Figure 2.6). Abundance was consistent throughout the experimental period (data not shown), however, at the beginning of the experiment the most abundant arthropods were beetles from Scarabeidae, with a shift in time to grasshoppers from Acrididae. Perhaps the beetle decline was due to many of the individuals were Japanese beetles, which may have reached the end of their adult life cycle. (Fleming, Walter 1972). While other research identifies cover crops are associated with increased arthropod diversity (Mosquera-Losada et al. 2005; Burgio et al. 2016), there was no relationship between cover crop and arthropod abundance ($p>0.10$, data not shown), with soybean, fallow, and pearl millet having the most families, and sorghum having the least (Table 2.5).

The % N in cover crop biomass was negatively correlated with arthropod abundance (Coefficient= -0.294, SE=0.092, Z=-3.185, P=0.0015) (Table 2.6). However, low numbers of arthropods were collected from cowpea and sunflower, which had the highest foliar concentration of nitrogen (Table 2.7). This may be due in part to the sunflower heads slowing down and catching the net during sweeps, possibly allowing arthropods to escape (personal observation), and sampling within cowpea was difficult due to deer herbivory. Arthropods will seek out plants with higher biomass because these more vigorous plants can provide more resources (Price 1991), and if these higher biomass plots contained lower foliar nitrogen, arthropods will increase their feeding rate to compensate for the poorer quality forage (Berner et al. 2005).

Discussion

Integrating The total number of birds found during the survey 6250 individual birds representing 48 species. Five species are considered obligate grassland users (horned lark, Savannah sparrow, Grasshopper sparrow, Dickcissel, Eastern meadowlark), while ten are facultative grassland users (Turkey vulture, Gadwall, American kestrel, Killdeer Mourning dove, Eastern kingbird, Eastern bluebird, Common yellowthroat, Brown-headed cowbird, and Red-winged blackbird) (Vickery et al. 2000). A study conducted in the Piedmont region of Georgia identified 42 species, of which 12 species were also identified in the present survey: Pileated woodpecker Mourning dove, Indigo bunting, American goldfinch (*Spinus tristis*), Tufted titmouse (*Baeolophus bicolor*), Blue jay (*Cfyanocitta cristata*), Summer tanager (*Piranga rubra*), Northern cardinal

(*Cardinalis cardinalis*), Common yellowthroat (*Geothlypis trichas*), Field sparrow, Eastern meadowlark, and Grasshopper sparrow (Johnston and Odum 1956). Another Georgia Piedmont survey determining at the effects of urbanization on neotropical migrants found 36 species, of which 7 species were also identified in the present survey: Ruby-throated hummingbird (*Archilochus colubris*), Killdeer (*Charadrius vociferus*), Eastern kingbird, Indigo bunting, Blue grosbeak (*Passerina caerulea*), Summer tanager, and Great crested flycatcher (*Myiarchus crinitus*) (Stratford and Robinson 2005).

A total of fourteen birds that were identified in the survey are considered to be of conservation concern in South Carolina: Great blue heron (*Ardea Herodias*), Red-shouldered hawk (*Buteo lineatus*), Pileated woodpecker, Blue grosbeak, Indigo bunting, Summer tanager, and Dickcissel (*Spiza americana*) are of moderate conservation concern, Wood duck, Chimney swift, Field sparrow, Eastern meadowlark, Eastern kingbird, Grasshopper sparrow, and Green heron are of highest conservation concern (SCDNR 2015).

Only about a fifth of point count H’ values fell within the typical range for this diversity index (1.5-3.5) (Anne 1994), and the overall average H’ across the entire sampling period was below average range (1.04). The overall average for *J* (0.28) was close to zero, indicating that there was more variation for taxa abundance during the survey (Kvålseth 2015). Most of the habitat in the survey area were pastures or agricultural fields, resulting in less structure, and have generally lower levels of bird diversity compared to shrublands and forests (Tramer 1969).

Habitat was significant for all diversity and equitability measures and was a predictor in all fit models. With the exception of fescue and radish without cattle, all three indices were highest in the fescue habitats, perhaps because these agroecological systems are most similar to the habitats surveyed to grassland systems (Weibull et al. 2003; Batáry et al. 2010). Further analysis identified that there were more grassland and forest birds within these habitats. Many of the pastures were close to patches of forest and sometimes contained one or two trees within them, providing both grassland and forest birds with cover, foraging opportunities, and potential song perches (Weibull et al. 2003; Batáry et al. 2010). Low-intensity grazing of cattle is beneficial to some bird species due to the vegetative structure caused by grazing, as well as the creation of bare patches for foraging (Powell 2008). In comparison, removing cattle from riparian areas in arid regions increased bird populations (Bleho et al. 2014). Grasslands in the Piedmont region have historically been maintained by both natural and anthropogenic fires (Tompkins et al. 2010; Benson 2011), and a mixture of burns and grazing could benefit bird populations (Powell 2008; Pillsbury et al. 2011). However, structural complexity of these agroecosystems may change in the future as farmers address pastures with fescue toxicosis issues. Fescue toxicosis is a disease caused by fungal endophytes that infect grazing animals, and has negative impacts on animal conditions and reproduction (Porter and Thompson 1992; Thompson and Stuedemann 1993). No treatment is known for this disease besides adapting management strategies to reduce livestock exposure to infected fescue (Roberts and Andrae 2004). These strategies include different grazing rotations, replacing with fescue varieties that have non-toxic novel endophytes, interseeding with other forages (Roberts and Andrae 2004), and removing and maintaining no pasture grass, all of which alter the structural complexity and may impact the capacity of these agroecosystems to sustain avian communities.

Cornfields had the lowest LS mean for all diversity and equitability indices. Intensive row cropping, such as corn, can lead to large decreases in bird populations (Warner 1994; Hill et al. 2014). However less intensive agriculture and cover cropping creates a more suitable habitat for birds in agroecosystems, providing them with cover and feeding opportunities (Hill et al. 2014; Wilcoxen et al. 2018).

Date was found to be significant for all three indices, and time of day were found to be significant for both H' and *J*. The significance of date is most likely due to the young of some species (such as American crows and Eastern bluebirds) fledging and beginning to leave the nest, resulting in increased numbers (White and Woolfenden 1973; McGowan 2001). Juvenile Eastern bluebirds were identified starting on 28 June 2019. Migratory species (such as Summer tanager, Blue grosbeak, and Mississippi kite (*Ictinia mississippiensis*)) might also arrive and leave at different dates, causing variation throughout the season. Resident birds sing less later in the breeding season, which may have resulted in lower detection rates (Skirvin 1981). Birds are easier to identify by ear in early morning close to sunrise and less likely to be detected as the day goes on as they become less vocal (Robbins 1981b). This may have been because of many observation events surveying was at cornfields during 08:00. Weather conditions like wind speed, cloud cover, and temperature did not affect bird diversity and equitability. Weather conditions can have varying effects on detecting any bird species present (O'Connor and Hicks 1980), and may be influenced by previous season nesting and food source availability (Tryjanowski 2000). As well as the extremes experienced over the sampling period (Robbins 1981a).

The majority of the arthropod families captured make up a large portion of the diet of most avian species observed during the experimental period (Frederick and Siegel-Causey 2000; McIntyre and Thompson 2003), and were of a size class favored by these species (Frederick and Siegel-Causey 2000; Whitman and Vincent 2008). The authors realize that bird diets include arthropods < 5 mm in size and thus the present results do not represent a complete assessment of avian forage potential. In addition, some of the bird species present forage on seed. American Goldfinch, for example, while not observed in the cover crop area during regular survey times, was found at nearby observation sites, and almost exclusively consume seeds (Frederick and Siegel-Causey 2000). Another consideration is that a large number of the avian species identified are considered pests in row crop agriculture, especially in the fall and winter when their diets shift from predominantly arthropods to seeds (Frederick and Siegel-Causey 2000; Linz et al. 2015; A. Baumgartner et al. 2019). Having an arthropod food source to keep them present in the spring and summer may increase fall and winter cash crop damage.

Arthropods, particularly generalist herbivores, seek out plants with higher nitrogen content (Joern and Behmer 1997). Our results parallel these results with the top model predicting arthropod abundance containing only % N in plant biomass.

Habitat is the greatest influence on summer bird diversity within a Southern Piedmont agroecosystem, followed by time of day, and time of the summer season. The habitat type that influenced diversity the most was the one most similar to native grasslands with structural diversity: fescue and forage radish with cattle. Some of these areas had forest surrounding them or contained trees and other objects like fences that add to structural complexity. If summer surveys need to be completed with minimal resources, the best results will be achieved by surveying in the second week of June, early morning hours (05:00-07:00), and in fescue and radish pastures with cattle present

A concern for consideration is the balance of ecosystem services and disservices, especially where cover crops are involved. Apart from Araneae, the taxon identified in this experiment are considered pest species with the potential to harm cash crop such as corn, wheat, oats, cotton, and tobacco (Prescott et al. 1986: Ribeiro et al. 2013: Araya and Foster 2015: USDA 2019) While attracting these insects may be detrimental to cash crop production, cover crops also have the potential to attract predatory insects and parasitoids, many of which function as pollinations in addition to pest control (Pemberton 2010) Many grassland birds observed are insectivores during the summer breeding season, and transition to consuming mostly grain during the fall, becoming cash crop pests(Frederick and Siegel-Causey 2000: A. Baumgartner et al. 2019).An alternative to this is using cover crops as a trap crop grown along with the cash crop, which can be used to divert pest away from the cash crop, or focusing them in an area for easier disposal (Shelton and Badenes-Perez 2006) Planting wildlife conservation sunflower plots (WCSP) near Red-winged blackbird roosts, resulted in birds removing 3.2 times more sunflower seed from WSCP treatments than from commercial sunflower fields nearby (Hagy et al. 2008). Many cover crops are recognized as being utilized in wildlife food plots to provide both forage and cover to game and nongame species (Donalty et al. 2003). With cover crops such as cowpea being favorable food plot crops (Edwards et al. 2004).

Conclusion

In the Southern Piedmont, agroecosystems with pasture grasslands as a primary component increased bird community dynamics. Structural complexity and disturbance influences bird community dynamics. The agroecosystems surveyed were variable with landscape features such as riparian, forest, and shrub areas adjacent or within, all which will influence the bird community. Disturbance by cattle increased bird diversity, and it is expected that since different livestock grazing causes varying types of disturbance (McMahan 1964), this too will influence bird community structure.

As cover crops increase in use, there are tradeoffs in the agroecological services they provide. They attract beneficial insects and provide seed and arthropod food sources for birds, yet they also attract pest insects. Whether the pest insects are kept from being problematic by the beneficial arthropods is an unknown at this time in these agroecosystems. However, there is potential to utilize summer cover crops along with cash crops to distract pest arthropods resulting in reducing pest pressure on the cash crop.

As natural grasslands are lost to development in the Southern Piedmont, agroecosystems will increase in importance for maintaining bird communities.

Figures and Tables

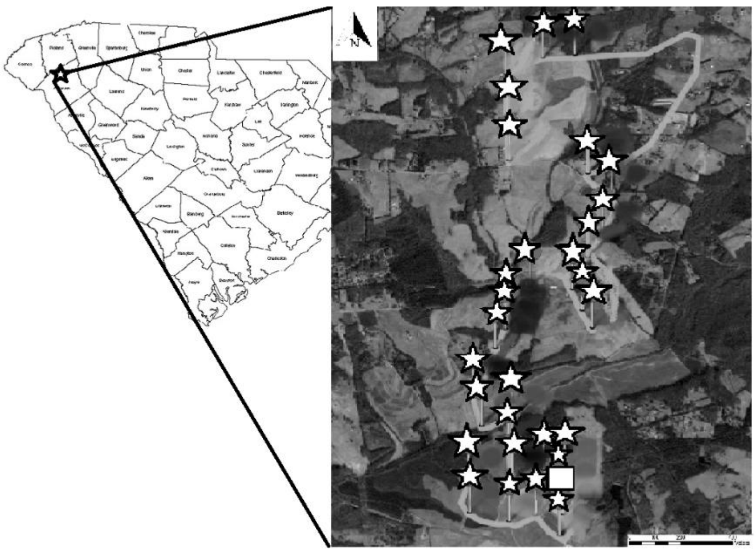

Figure 2.1. The summer bird in agroecological systems survey was conducted in the Southern Piedmont region of South Carolina. Each star indicates a point count within the survey that were approximately 200 m apart from each other. The square represents where the cover crop experiments were planted.

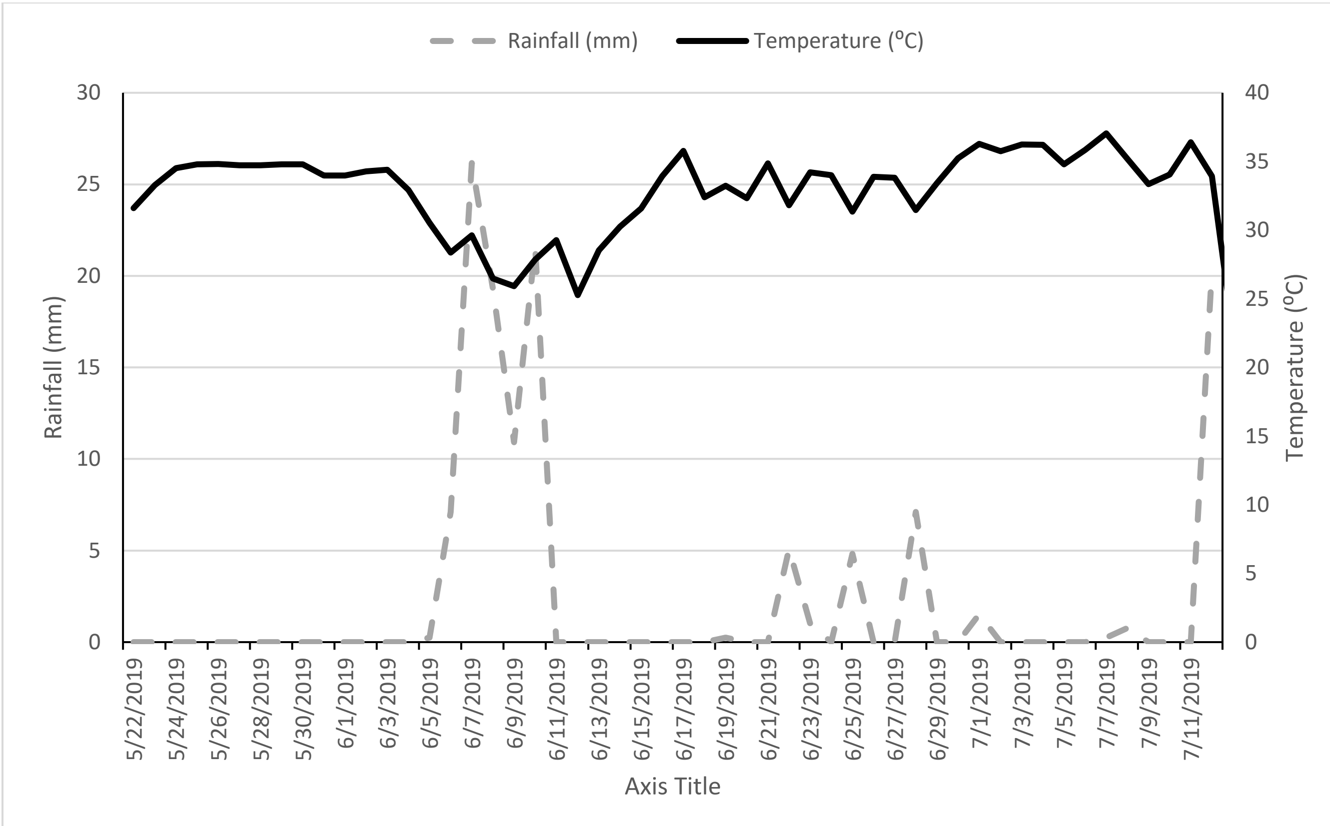

Figure 2.2. Rainfall and Temperature during the 2019 summer bird survey at Clemson University's Simpson Experiment Station in Pendleton, South Carolina.

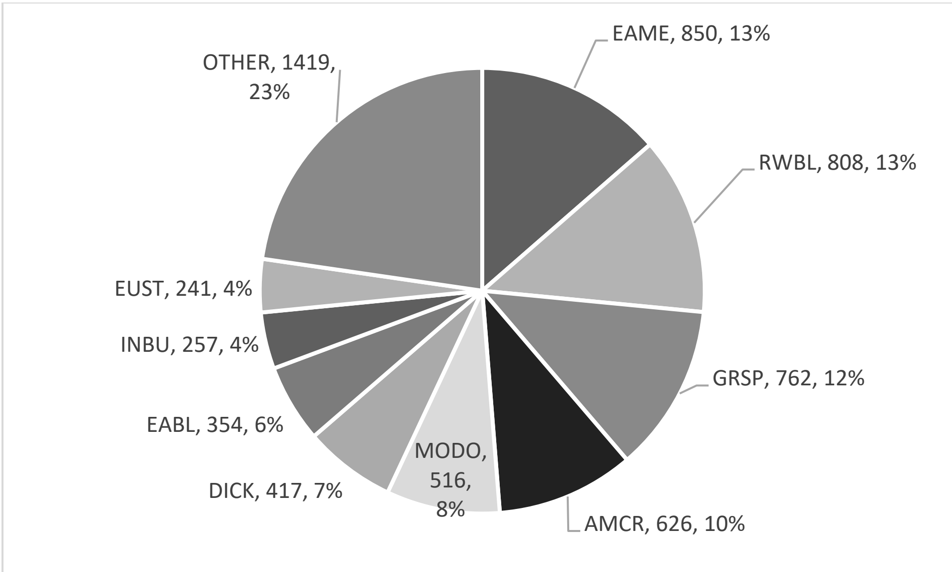

Figure 2.3: Total number and percentage of bird species detected during the survey period. Other represents 39 species in which each represented less than 4% of all birds detected. EAME = Eastern meadowlark (*Sturnella magna*), RWBL= Red-winged blackbird (*Agelaius phoeniceus)*, GRSP= Grasshopper sparrow (*Ammodramous savannarum)*, AMCR= American crow (*Corvus brachyrhynchos)*, MODO= Mourning dove (*Zenadia macroura*), DICK= Dickcissel (*Spiza americana*), EABL= Eastern bluebird (*Sialia sialis)*, INBU= Indigo bunting (*Passerina cyanea*), EUST= European starling (*Sturnus vulgaris).*

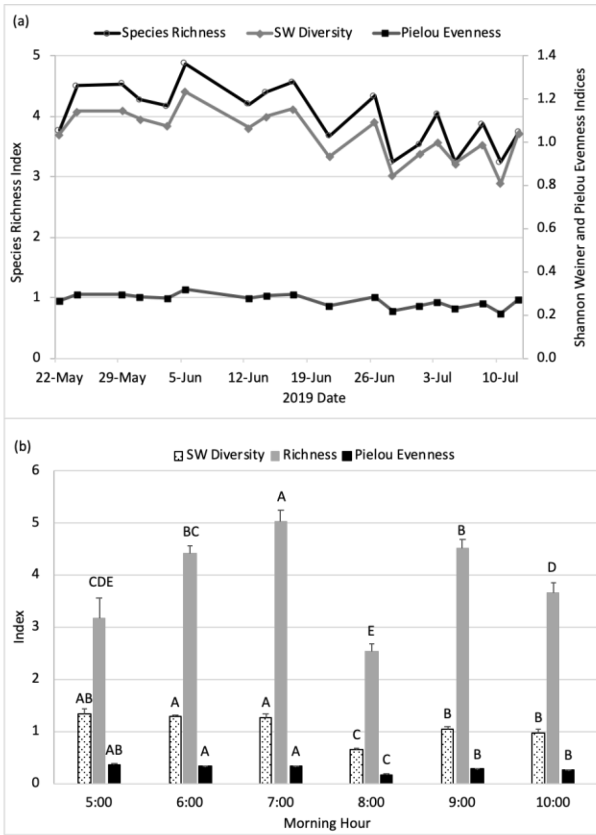

Figure 2.4. Summer bird diversity and equitability indices as influenced by (a) date and (b) time in a Southern Piedmont agroecosystem. Bars with the same letter within index are statistically similar at α=0.05.

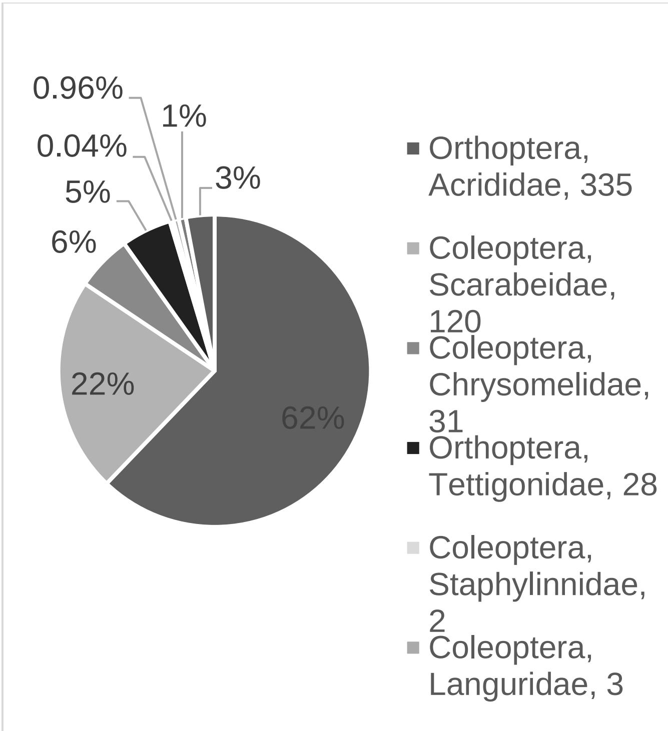

Figure 2.5. Arthropod order, Family (abundance) across all cover crop treatments during the sampling period

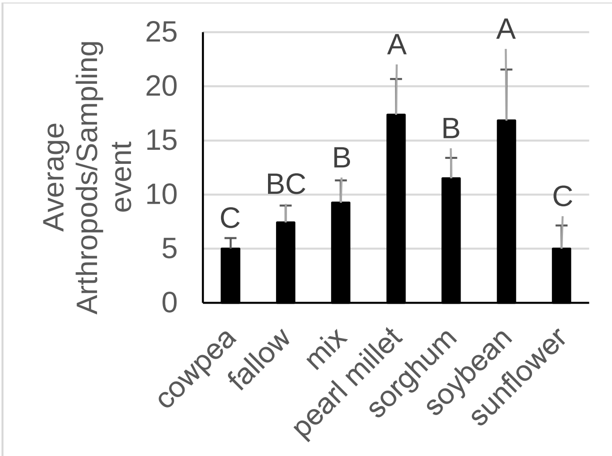

Figure 2.6: Average abundance of arthropods per sampling event for each cover crop treatment. Bars indicated standard error of the mean. Bars labelled with different letters indicate statistical differences.

Table 2.1. Table of main effect significance and standard error (SE) of main effects for Shannon-Weiner Diversity (H'), Pielou evenness (J), and richness indices. Standard error degrees of freedom was 525. Bolded terms are statistically significant at α=0.05

	DF	**H'**		***J***		**Richness**	
		P value	SE	P value	SE	P value	SE
Date	1	**0.0047**	0	**0.0047**	0	**0.0002**	0
Hour	1	**0.0043**	0.0188	**0.0043**	0.0049	0.3370	0.0817
Temp	1	0.7991	0.0218	0.7991	0.0056	0.9090	0.0946
Wind	3	0.4174	0.0603	0.4174	0.0156	0.8999	0.2617
Sky	4	0.4498	0.0794	0.4498	0.0205	0.7933	0.3444
Habitat	5	**<0.0001**	0.0654	**<0.0001**	0.0169	**<0.0001**	0.2836

Table 2.2: Least square means of diversity and equitability indices for habitat types observed during bird survey. LS means followed by the same letter within a column are statistically similar when compared using a Student's T-test at a significance level 0.05.

Habitat	Shannon-Weiner (H')	Richness	Evenness (*J*)
Fescue with cattle	1.3 A	5.0 A	0.34 A
Fescue without cattle	1.2 A	4.6 AB	0.32 A
Fescue and radish with cattle	1.4 A	4.8 AB	0.37 A
Fescue and radish without cattle	0.9 B	4.1 B	0.24 B
Mixed use	0.8 B	3.5 C	0.22 B
Corn	0.3 C	1.3 D	0.09 C

Table 2.3. Model selection for predictors of (a) Shannon-Weiner diversity (H’), (b) Pielou evenness (*J*), and (c) richness during the 2019 summer bird survey of Southern Piedmont agroecosystems.

Model	Intercept	Habitat	Hour	Date	AIC	Delta	Weight
(a) H’							
3	1.5	-0.4	-0.1		602	0	0.9
2	1.5	-0.4	-0.1	-0.1	607	5	0.1
1	1.0	-0.4			628	26	0.0
(b) J							
3	0.4	-0.1	< 0.1		-860	0	0.9
2	0.4	-0.1	<-0.1	<-0.1	-855	5	0.1
1	0.3	-0.1			-834	26	0.0
(c) richness							
3	3.5	-1.5	-0.1	-0.5	2189	0	0.4
2	2.8	-1.5			2189	0.2	0.3
1	2.8	-1.5		-0.5	2189	0.3	0.3

Table 2.4. Model selection for predictors of presence of birds of high conservation concern in South Carolina documented during the 2019 summer bird survey of Southern Piedmont agroecosystems: (a) Grasshopper sparrow, (b) Eastern meadowlark, and (c) Field sparrow.

Model	Intercept	Habitat	Hour	Date	AIC	Delta	Weight
(a) Grasshopper sparrow							
3	2.1	0.7	-0.1		1997	0	0.7
2	1.8	0.7	-0.1	0.3	1999	2	0.3
1	1.1	0.7			2002	5	0.0
(b) Eastern meadowlark							
3	0.7	1.3			2261	0	0.6
2	1.1	1.3	-0.1		2262	1	0.4
1	0.4	1.3	-0.1	0.7	2279	18	0.0
(c) Field sparrow							
3	0.6	-0.5			919	0.0	0.5
2	0.5	-0.5		0.1	919	0.7	0.4
1	0.6	-0.5	-<0.1	0.1	921	2.5	0.1

Table 2.5. Arthropod taxa of avian forage importance found in the cover crop treatments

Crop	Taxa
Cowpea	Acrididae, Chrysomelidae, Scarabaeidae, Tettigonidae, Araneae
Fallow	Acricidae, Chrysomelidae, Lepidoptera, Scarbaeidae, Tettigonidae, Araneae
Mix	Acrididae, Chrysomelidae, Scarabaeidae, Tettigonidae, Araneae
P. Millet	Acricidae, Chrysomelidae, Languriidae, Scarabeidae, Tettigonidae, Araneae
Sorghum	Acrididae, Chrysomelidae, Tettigonidae, Araneae
Soybean	Acricidae, Chrysomelidae, Languriidae, Scarabeidae, Tettigonidae, Araneae
Sunflower	Acrididae, Chrysomelidae, Scarabaeidae, Tettigonidae, Araneae

Table 2.6. Model selection for the top crop-based predictors of arthropod abundance (Biomass, % Foliar C, % Foliar N) across all cover crop treatments.

Model	Intercept	Biomass	%C	%N	AICc	Delta	Weight
7	2.16		0.13	-0.16	387.80	0.00	0.43
5	2.17			-0.17	388.80	1.04	0.25
8	2.16	-0.04	0.12	-0.18	389.80	2.03	0.15
6	2.16	-0.06		-0.20	390.10	2.34	0.13
3	2.17		0.16		393.80	6.00	0.02
4	2.17	0.03	0.16		396.00	8.26	0.01
1	2.18				397.20	9.42	0.00
2	2.18	0.01			399.50	11.70	0.00

Table 2.7. Least square means for cover crop nitrogen (N), and carbon (C) concentrations in leaf tissue (mg g^{-1}), and total biomass (kg ha^{-1}).

	N	C	Biomass
	------------mg g^{-1}-------------		kg ha^{-1}
Sunflower	1.85 b$^{\alpha}$	44.08 ab	2065 b
Cowpea	2.72 a	42.25 bc	1316 c
Sorghum	1.32 c	45.05 a	2911 a
Soybean	1.64 bc	44.84 a	787 d
P. Millet	1.64 bc	43.38 ab	2396 b
Mix	1.62 bc	43.18 abc	2032 b
Fallow	1.62 bc	41.45 c	2372 b
P Value	<0.0001	0.0078	<0.0001
Std Error	0.1422	1.0843	186

α LS means followed by the same letter within a column are statistically similar when compared using a Student's T test at a significance level 0.05.

Works Cited

A. BAUMGARTNER, J., A. HAIGHT, J. MCPROUD, R. FARM, D. CHAMBERLAIN, C. FARMS, ET AL. [online]. 2019. Supporting Beneficial Birds and Managing Pest Birds.

ALLEN, B., M. KON and Y. BAR-YAM [online]. 2009. A new phylogenetic diversity measure generalizing the shannon index and its application to phyllostomid bats. American Naturalist 174: 236–243. The University of Chicago Press.

ANNE. 1994. Measuring biological diversity. Environmental and Ecological Statistics 1: 95–103. Blackwell Publishing.

ARAYA, J.E. and J.E. FOSTER [online]. 2015. Insect, Mite, and Nematode Pests of Oat. In pp. 427–471.

ASKINS, R.A. [online]. 1999. History of grassland birds in eastern North America. *Studies in Avian Biology*. <http://digitalcommons.conncoll.edu/biofacpub> (7 May 2020).

BARDGETT, R.D. and R. COOK. 1998. Functional aspects of soil animal diversity in agricultural grasslands. Applied Soil Ecology 10: 263–276. Elsevier.

BATÁRY, P., T. MATTHIESEN and T. TSCHARNTKE. 2010. Landscape-moderated importance of hedges in conserving farmland bird diversity of organic vs. conventional croplands and grasslands. Biological Conservation 143: 2020–2027.

Elsevier.

BENSON, J.D. [online]. 2011. Characterization of Piedmont prairie sites in North and South Carolina.

BERG, Å. 2002. Breeding birds in short-rotation coppices on farmland in central Sweden - The importance of Salix height and adjacent habitats. Agriculture, Ecosystems and Environment 90: 265–276. Elsevier.

BERNER, D., W.U. BLANCKENHORN and C. KÖRNER [online]. 2005. Grasshoppers cope with low host plant quality by compensatory feeding and food selection: N limitation challenged. Oikos 111: 525–533. John Wiley & Sons, Ltd.

BLEHO, B.I., N. KOPER and C.S. MACHTANS [online]. 2014. Direct effects of cattle on grassland birds in Canada. Conservation Biology 28: 724–734. Blackwell Publishing Inc.

BLUBAUGH, C.K., L. CARPENTER-BOGGS, J.P. REGANOLD, R.N. SCHAEFFER and W.E. SNYDER [online]. 2018. Bacteria and competing herbivores weaken top–down and bottom–up aphid suppression. Frontiers in Plant Science 9: 1239. Frontiers Media S.A.

BOLLINGER, E.K. [online]. 2001. Ecology and Conservation of Grassland Birds of the Western Hemisphere Peter D. Vickery James R. Herkert. The Auk 118: 806–808.

BUFFINGTON, M.L. and R.A. REDAK. 1998. A comparison of vacuum sampling versus sweep-netting for arthropod biodiversity measurements in California coastal sage scrub. Journal of Insect Conservation 2: 99–106. Springer.

BURGIO, G., E. MARCHESINI, N. REGGIANI, G. MONTEPAONE, P. SCHIATTI and D. SOMMAGGIO [online]. 2016. Habitat management of organic vineyard in Northern Italy: The role of cover plants management on arthropod functional biodiversity. Bulletin of Entomological Research 106: 759–768.

CEBALLOS, G., A. DAVIDSON, R. LIST, J. PACHECO, P. MANZANO-FISCHER, G. SANTOS-BARRERA and J. CRUZADO. 2010. Rapid decline of a grassland system and its ecological and conservation implications. PLoS ONE 5. Public Library of Science.

DAVIS, J.E., C. MCRAE, B.L. ESTEP, L.S. BARDEN and J.F. MATTHEWS [online]. 2002. Vascular flora of Piedmont prairies: Evidence from several prairie remnants. Castanea 67: 1–12.

DICKSON, T.L. and B.J. WILSEY. 2009. Biodiversity and tallgrass prairie decomposition: The relative importance of species identity, evenness, richness, and micro-topography. Plant Ecology 201: 639–649.

DONALTY, S., S.E. HENKE and C.L. KERR. 2003. Use of winter food plots by nongame wildlife species. Wildlife Society Bulletin 31: 774–778.

DOXON, E.D., C.A. DAVIS and S.D. FUHLENDORF [online]. 2011. Comparison of two methods for sampling invertebrates: vacuum and sweep-net sampling. Journal of Field Ornithology 82: 60–67. Blackwell Publishing Inc.

EDGAR, W.B. [online]. 1998. South Carolina: A History - Walter B. Edgar - Google

Books. University of South Carolina Press.

EDWARDS, NICOLE T., OTIS, D.L. [online]. 1999. Avian Communities and Habitat Relationships in South Carolina Piedmont Beaver Ponds. The American Midland Naturalist 141: 158–171.

EDWARDS, S.L., S. DEMARAIS, B. WATKINS and B.K. STRICKLAND [online]. 2004. White-tailed deer forage production in managed and unmanaged pine stands and summer food plots in Mississippi. Wildlife Society Bulletin 32: 739–745. John Wiley & Sons, Ltd.

FLEMING, WALTER, E. [online]. 1972. Biology of the Japanese Beetle - Walter Ernest Fleming. United States Department of Agriculture, Washington, D.C.

FLETCHER, R.J. and R.R. KOFORD [online]. 2002. Habitat and Landscape Associations of Breeding Birds in Native and Restored Grasslands. The Journal of Wildlife Management 66: 1011.

FREDERICK, P. and D. SIEGEL-CAUSEY [online]. 2000. All About Birds - Cornell Lab of Ornithology. <https://www.allaboutbirds.org/guide/> (27 April 2020).

GHAZALI, A., S. ASMAH, M. SYAFIQ, M.S. YAHYA, N. AZIZ, L.P. TAN, ET AL. 2016. Effects of monoculture and polyculture farming in oil palm smallholdings on terrestrial arthropod diversity. Journal of Asia-Pacific Entomology 19: 415–421. Elsevier B.V.

HAGY, H.M., G.M. LINZ and W.J. BLEIER. 2008. Optimizing the use of decoy plots for blackbird control in commercial sunflower. Crop Protection 27: 1442–1447. Elsevier.

HILL, J.M., J.F. EGAN, G.E. STAUFFER and D.R. DIEFENBACH. 2014. Habitat availability is a more plausible explanation than insecticide acute toxicity for U.S. grassland bird species declines. PLoS ONE 9. Public Library of Science.

HOOKS, C.R.R., R.R. PANDEY and M.W. JOHNSON [online]. 2003. Impact of avian and arthropod predation on lepidopteran caterpillar densities and plant productivity in an ephemeral agroecosystem. Ecological Entomology 28: 522–532. John Wiley & Sons, Ltd.

HOVICK, T.J., R.D. ELMORE, S.D. FUHLENDORF, D.M. ENGLE and R.G. HAMILTON [online]. 2015. Spatial heterogeneity increases diversity and stability in grassland bird communities. Ecological Applications 25: 662–672. Ecological Society of America.

JOERN, A. and S.T. BEHMER. 1997. Importance of dietary nitrogen and carbohydrates to survival, growth, and reproduction in adults of the grasshopper Ageneotettix deorum (Orthoptera: Acrididae). Oecologia 112: 201–208. Springer.

JOHNSTON, D.W. and E.P. ODUM. 1956a. Breeding Bird Populations in Relation to Plant Succession on the Piedmont of Georgia. Ecology 37: 50–62. Wiley.

--- [online]. 1956b. Breeding Bird Populations in Relation to Plant Succession on the Piedmont of Georgia. Ecology 37: 50–62.

JONES, G.A. and J.L. GILLETT. 2005. INTERCROPPING WITH SUNFLOWERS TO ATTRACT BENEFICIAL INSECTS IN ORGANIC AGRICULTURE. Florida Entomologist 88: 91–96. Florida Entomological Society.

KILGO, J.C.. ., D.L.. GARTNER, B.R.. CHAPMAN, J.. J.B.. DUNNING, K.E.. FRANZREB, GAUTHREAUX SIDNEY A., ET AL. 2002. A Test of an Expert-Based Bird-Habitat Relationship Model in South Carolina. Wildlife Society Bulletin 30: 783–793.

KILGO, J.C., R.A. SARGENT, K. V MILLER and B.R. CHAPMAN. 1973. Landscape Influences on Breeding Bird Communities in Hardwood Fragments in South Carolina. Wildlife Society Bulletin 25: 878–885. Winter.

KVÅLSETH, T.O. 2015. Evenness indices once again: critical analysis of properties. SpringerPlus 4. SpringerOpen.

LESLIE, A.W., K.H. WANG, S.L.F. MEYER, S. MARAHATTA and C.R.R. HOOKS [online]. 2017. Influence of cover crops on arthropods, free-living nematodes, and yield in a succeeding no-till soybean crop. Applied Soil Ecology 117–118: 21–31.

LINDBORG, R., J. PLUE, K. ANDERSSON and S.A.O. COUSINS. 2014. Function of small habitat elements for enhancing plant diversity in different agricultural landscapes. Biological Conservation 169: 206–213. Elsevier.

LINZ, G.M., E.H. BUCHER, S.B. CANAVELLI, E. RODRIGUEZ and M.L. AVERY [online]. 2015. Limitations of population suppression for protecting crops from bird depredation: A review. *Crop Protection*.

<https://digitalcommons.unl.edu/icwdm_usdanwrc/1707> (30 April 2020).

MA, M. [online]. 2005. Species richness vs evenness: Independent relationship and different responses to edaphic factors. Oikos 111: 192–198. John Wiley & Sons, Ltd.

MATTHEWS, E., R. PAYNE, M. ROHWEDER and S. MURRAY. 2001. Pilot Analysis of Global Ecosystems: Forest Ecosystems. In Pilot Analysis of Global Ecosystems p. .

MAYER, A.L. and S.L. PIMM [online]. 1997. Tropical rainforests: Diversity begets diversity. Current Biology 7: 430–432.

MCCRACKEN, J.D. 2005. Where the bobolinks roam: The plight of north America's grassland birds. Biodiversity 6: 20–29.

MCDONALD, C., R. SMITH, M. SCOTT and J. DICK. 2010. Using indices to measure biodiversity change through time. METMAV International Workshop on Spatio-Temporal Modelling: 1–5.

MCGOWAN, K.J. 2001. Demographic and behavioral comparisons of suburban and rural American Crows. In Avian Ecology and Conservation in an Urbanizing World pp. 365–381. Norwell.

MCINTYRE, N.E. and T.R. THOMPSON. 2003. A Comparison of Conservation Reserve Program Habitat Plantings with Respect to Arthropod Prey for Grassland Birds. The American Midland Naturalist 150: 291–301. University of Notre Dame.

MCMAHAN, C.A. [online]. 1964. Comparative Food Habits of Deer and Three Classes of

Livestock. The Journal of Wildlife Management 28: 798.

MOSQUERA-LOSADA, R., A. RIGUERO-RODRIGUEZ and J. MCADAM [online]. 2005. Silvopastoralism and sustainable land management. Proceedings of an international congress on silvopastoralism and sustainable management held in Lugo, Spain, April 2004. In Silvopastoralism and sustainable land management. Proceedings of an international congress on silvopastoralism and sustainable management held in Lugo, Spain, April 2004 p. .

NIEMELÄ, J. [online]. 2000. Biodiversity monitoring for decision-making. Annales Zoologici Fennici 37: 307–317.

O'CONNOR, R.J. and R.K. HICKS [online]. 1980. The influence of weather conditions on the detection of birds during common birds census fieldwork. Bird Study 27: 137–151.

OBASI, K.O., N.D. IJERE and R.I. OKECHUKWU. 2013. Species Diversity and Equitability Indices of Some Fresh Water Species in Aba River and Azumini Blue River , Abia State Nigeria 2: 238–242.

OKSANEN, J., R. KINDT, P. LEGENDRE, B. O'HARA, G. SIMPSON, P. SOLYMOS, ET AL. 2009. The Vegan Package.

PEMBERTON, R.W. 2010. Biotic resource needs of specialist Orchid pollinators. Botanical Review 76: 275–292.

PILLSBURY, F.C., J.R. MILLER, D.M. DEBINSKI and D.M. ENGLE [online]. 2011. Another tool in the toolbox? Using fire and grazing to promote bird diversity in highly fragmented landscapes. Ecosphere 2: art28. Ecological Society of America.

PORTER, J.K. and F.N. THOMPSON [online]. 1992. Effects of fescue toxicosis on reproduction in livestock. Oxford Academic. *Journal of animal science*. <https://academic.oup.com/jas/article/70/5/1594-1603/4632015> (7 July 2020).

POWELL, A.F.L.A. [online]. 2008. Responses of breeding birds in tallgrass prairie to fire and cattle grazing. Journal of Field Ornithology 79: 41–52. Blackwell Publishing Inc.

PRESCOTT, J., P. BURNETT and E. SAARI [online]. 1986. Wheat diseases and pests. A guide for field identification. … for Field Identification.

PRICE, P.W. 1991. The Plant Vigor Hypothesis and Herbivore Attack. Oikos 62: 244.

REDDY, K.N., R.M. ZABLOTOWICZ, M.A. LOCKE and C.H. KOGER. 2003. Cover crop, tillage, and herbicide effects on weeds, soil properties, microbial populations, and soybean yield. Weed Science 51: 987–994. Cambridge University Press (CUP).

REGAN, H.M., F.W. DAVIS, S.J. ANDELMAN, A. WIDYANATA and M. FREESE. 2007. Comprehensive criteria for biodiversity evaluation in conservation planning. Biodiversity and Conservation 16: 2715–2728. Springer.

RIBEIRO, R.C., W.D.P. LEMOS, J.C.M. PODEROSO, T.G. PIKART and J.C. ZANUNCIO [online]. 2013. New Record of Grasshopper (Orthoptera: Acrididae & Romaleidae) Defoliators and Population Dynamics of Insects on Crops of Heliconia spp in the

Amazon. Florida Entomologist 96: 225–228. Florida Entomological Society.

RISSER, P.G. and E.O. WILSON. 1988. Diversity in and among grasslands. In Biodiversity pp. 176–180. National Academies Press (US).

ROBBINS, C.S. 1981a. BIRD ACTIVITY LEVELS RELATED TO WEATHER. In Studies in Avian Biology p. .

ROBBINS, C.S. 1981b. EFFECT OF TIME OF DAY ON BIRD ACTIVITY CHANDLER. Studies in Avian Biology 6: 940–947.

ROBERTS, C. and J. ANDRAE [online]. 2004. Tall Fescue Toxicosis and Management. Crop Management 3: 1–18. American Society of Agronomy.

ROBERTSON, B.A., P.J. DORAN, L.R. LOOMIS, J.R. ROBERTSON and D.W. SCHEMSKE [online]. 2011. Perennial biomass feedstocks enhance avian diversity. GCB Bioenergy 3: 235–246. Blackwell Publishing Ltd.

ROBINSON, S.K., F.R. THOMPSON, T.M. DONOVAN, D.R. WHITEHEAD and J. FAABORG. 1999. Regional forest fragmentation and the nesting success of migratory birds. In NCASI Technical Bulletin p. .

RUDD, W.G. and R.L. JENSEN [online]. 1977. Sweep Net and Ground Cloth Sampling for Insects in Soybeans1. Journal of Economic Entomology 70: 301–304.

SAUER, J.R., J.E. FALLON and R. JOHNSON. 2003. Use of North American Breeding Bird Survey Data to Estimate Population Change for Bird Conservation Regions. The Journal of Wildlife Management 67: 372.

SCDNR [online]. 2015. SCDNR - 2015 State Wildlife Action Plan. <http://www.dnr.sc.gov/swap/index.html> (28 May 2020).

SCHAUFF, M.E. 2001. Collecting And Preserving Insects And Mites Techniques And Tools. Update and modified WWW version of: Steyskal, GC, Murphy, WL & Hoover, EM (Eds.)(1986) Insects and mites: techniques for collectionand preservation. Agricultural Research Service, USDA, Miscellaneous Publication 1443: x.

SHELTON, A.M. and F.R. BADENES-PEREZ [online]. 2006. CONCEPTS AND APPLICATIONS OF TRAP CROPPING IN PEST MANAGEMENT. Annual Review of Entomology 51: 285–308. Annual Reviews.

SIEMANN, E., J. HAARSTAD and D. TILMAN [online]. 1999. Dynamics of plant and arthropod diversity during old field succession. Ecography 22: 406–414. Blackwell Munksgaard.

SKIRVIN, A.A. 1981. Effect of time of day and time of season on the number of observations and density estimates of breeding birds. In Studies in Avian Biology p. .

SORRELLS, R.T. 1984. The Clemson Experimental Forest: its first fifty years: 52.

STRATFORD, J.A. and W.D. ROBINSON. 2005. Distribution of neotropical migratory bird species across an urbanizing landscape. *Urban Ecosystems*. .

THOMPSON, F.N. and J.A. STUEDEMANN. 1993. Pathophysiology of fescue toxicosis.

Agriculture, Ecosystems and Environment 44: 263–281. Elsevier.

TOMPKINS, R.D. and W.C. BRIDGES [online]. 2013. Restoration and plant species diversity of an Eastern prairie. In Native Plants Journal p. .

TOMPKINS, R.D., C.M. LUCKENBAUGH, W.C. STRINGER, K.H. RICHARDSON, E.A. MIKHAILOVA and W.C. BRIDGES. 2010. Suther Prairie: Vascular Flora, Species Richness, and Edaphic Factors. Castanea 75: 232–244.

TRAMER, E.J. 1969. Bird Species Diversity: Components of Shannon's Formula. Ecology 50: 927–929.

TRYJANOWSKI, P. [online]. 2000. Changes in breeding populations of some farmland birds in W Poland in relation to changes in crop structure, weather conditions and number of predators. *Folia Zoologica*. <https://www.researchgate.net/publication/285739258_Changes_in_breeding_populations_of_some_farmland_birds_in_W_Poland_in_relation_to_changes_in_crop_structure_weather_conditions_and_number_of_predators> (6 June 2020).

USDA [online]. 2019. USDA/NASS 2018 State Agriculture Overview for Wyoming. *USDA/NASS*. <https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=SOUTH CAROLINA> (6 May 2020).

VICKERY, P.D., J.R. HERKERT, F.L. KNOPF and C.E. KELLER [online]. 2000. Grassland birds : an overview of threats and recommended management strategies. In

Strategies for bird conservation: The Partners in Flight planning process; Proceedings of the 3rd Partners in Flight Workshop; 1995 October 1-5; Cape May, NJ (R. Bonney, N. Pashley, David, J. Cooper, Robert & L. Niles, eds.), pp. 74–77. Cape May, NJ.

WARNER, R.E. 1994. Agricultural Land Use and Grassland Habitat in Illinois: Future Shock for Midwestern Birds? Conservation Biology 8: 147–156.

WEIBULL, A.-C., O. OSTMAN and A. GRANQVIST. 2003. Species richness in agroecosystems: the effect of landscape, habitat and farm management. In Biodiversity and Conservation p. . Kluwer Academic Publishers.

WHITE, R., S. MURRAY and M. ROHWEDER. 2000. PILOT ANALYSIS OF GLOBAL ECOSYSTEMS: Grassland Ecosystems.

WHITE, S.C. and G.E. WOOLFENDEN [online]. 1973. Breeding of the Eastern Bluebird in Central Florida. Bird-Banding 44: 110.

WHITMAN, D.W. and S. VINCENT. 2008. Large size as an antipredator defense in an insect. Journal of Orthoptera Research 17: 353–371.

WILCOXEN, C.A., J.W. WALK and M.P. WARD. 2018a. Use of cover crop fields by migratory and resident birds. Agriculture, Ecosystems and Environment 252: 42–50. Elsevier B.V.

WILCOXEN, C.A., J.W. WALK and M.P. WARD [online]. 2018b. Use of cover crop fields by migratory and resident birds. Agriculture, Ecosystems and Environment 252: 42–

50.

WILSEY, B.J. and C. POTVIN. 2000. Biodiversity and ecosystem functioning: Importance of species evenness in an old field. Ecology 81: 887–892. John Wiley & Sons, Ltd.

WITH, K.A., A.W. KING and W.E. JENSEN. 2008. Remaining large grasslands may not be sufficient to prevent grassland bird declines. Biological Conservation 141: 3152–3167.

WOOD, S., K. SEBASTIAN and S.J. SCHERR. 2000. PILOT ANALYSIS OF GLOBAL ECOSYSTEMS: Agroecosystems.

WRETENBERG, J., T. PÄRT and Å. BERG. 2010. Changes in local species richness of farmland birds in relation to land-use changes and landscape structure. Biological Conservation 143: 375–381.